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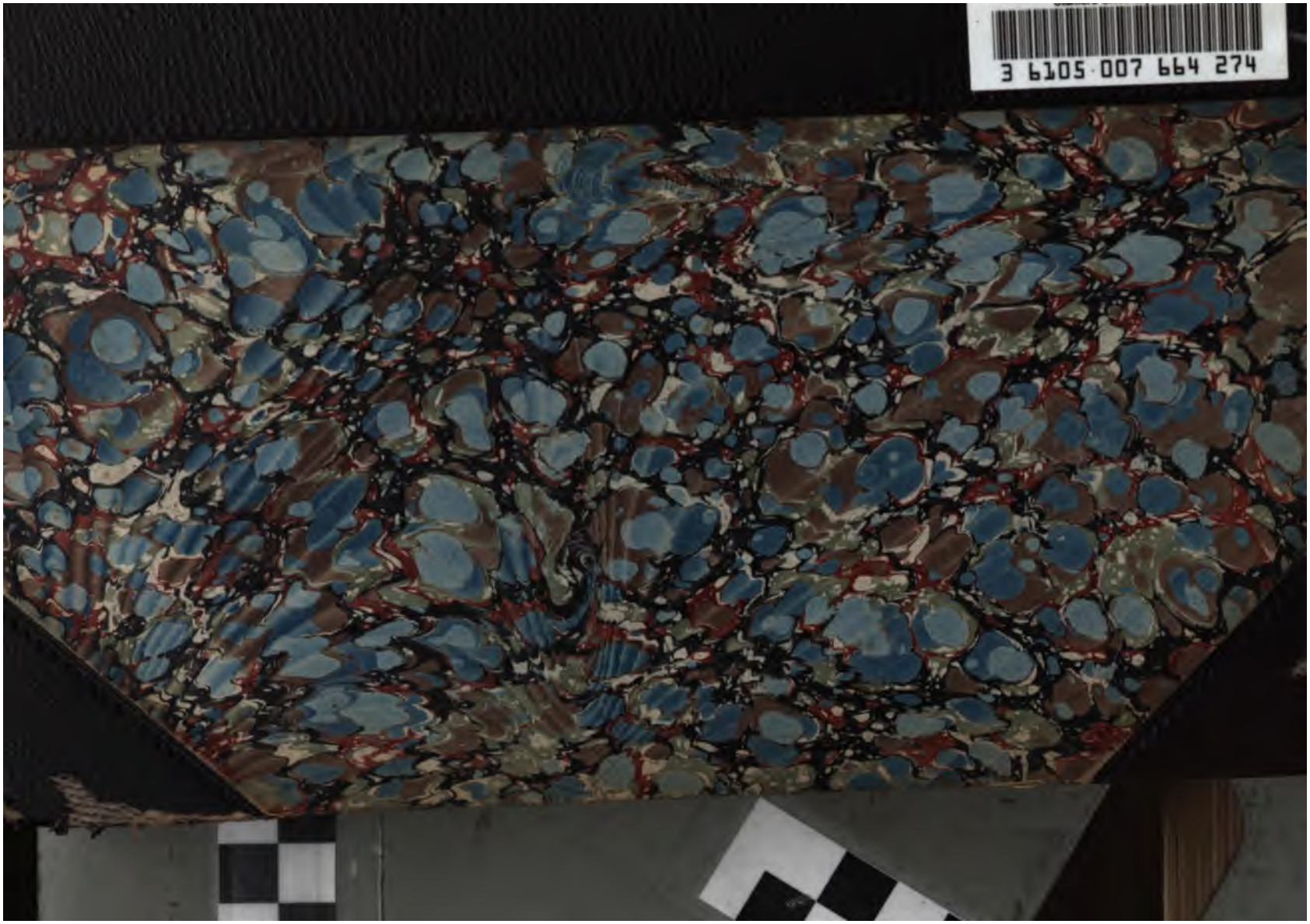
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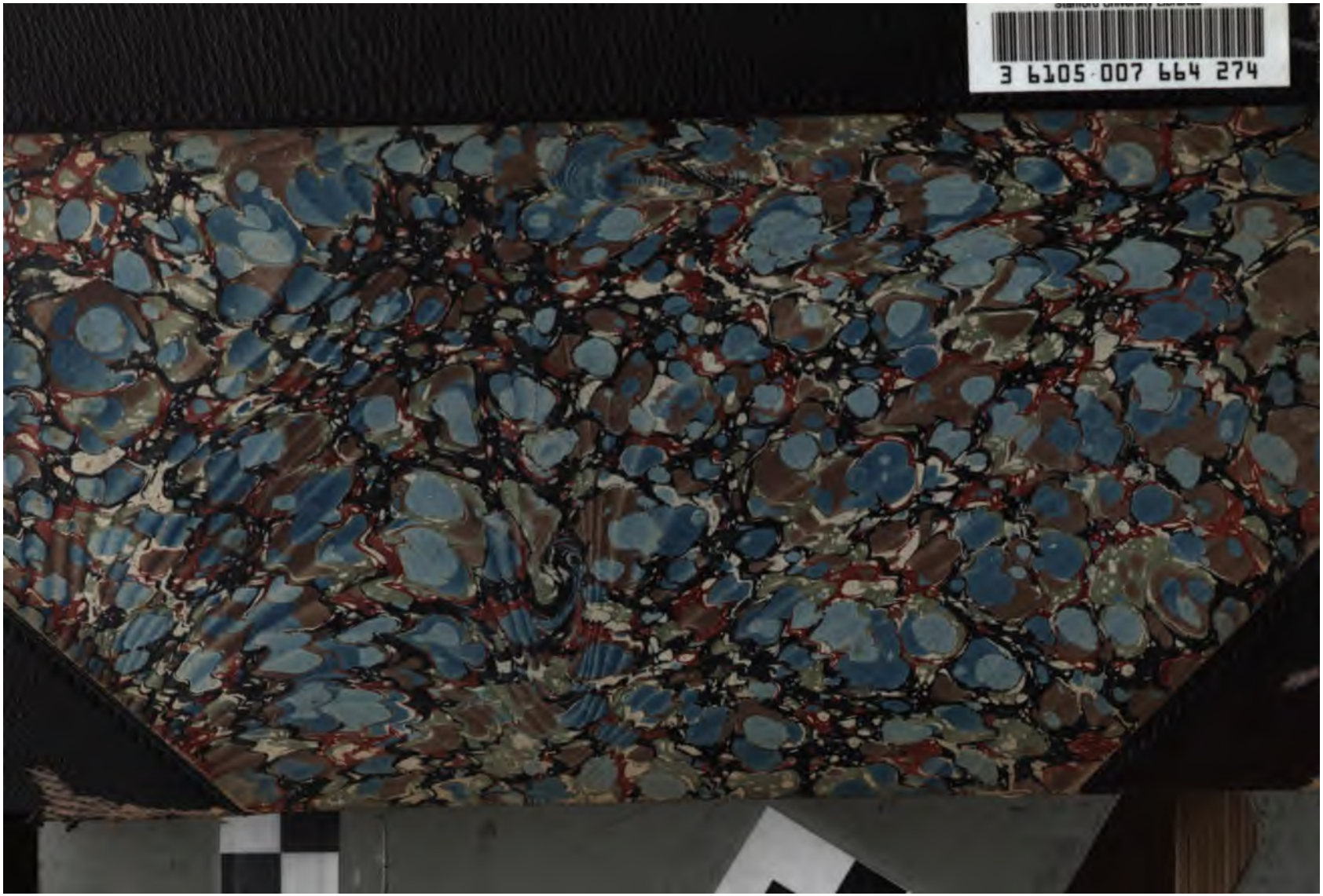
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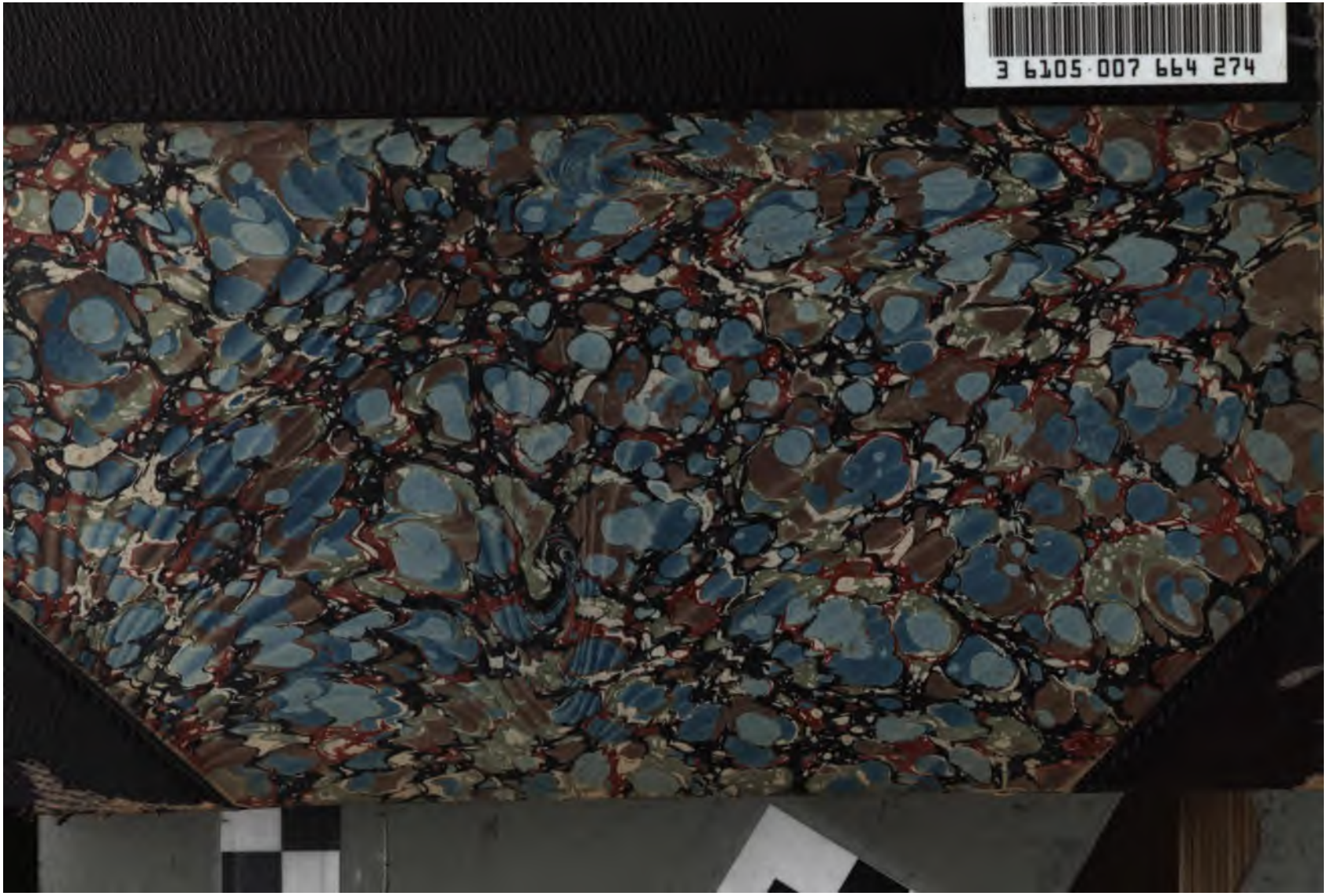
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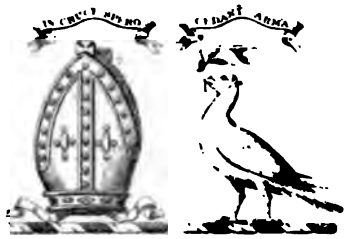

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VOLUME THE ELEVENTH.

1889-90.

EDITED BY

G. S. BOULGER, F.L.S., F.G.S.,

Professor of Geology in the City of London College.



(Authors alone are responsible for the opinions and facts stated in their respective Papers.)

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CORRIGENDA.

p. iii, line 26, *for* Stockwell, *read* Streatham.
p. xcix, line 20, *for* Holm Culkam, *read* Holm Cultram.
p. c, line 6 from bottom, *for* Henry, *read* Edward.
p. 315, line 15, *for* now, *read* how.
p. 325, line 20, *for* size and bulk, *read* shape and bulk.
p. 327, line 7 from bottom, *for* Bracton, *read* Bacton.
p. 423, line 24, *for* Eiffel, *read* Eifel.
p. 442, line 35, *for* F. G. Hutton, *read* F. W. Hutton.
p. 473, line 16, and p. 480, line 9, for *antiquitatus*, read *antiquitatis*.
Passim, for *Limnæa peregra*, read *Limnæa pereger*.

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

ORDINARY MEETING.

FRIDAY, NOVEMBER 2ND, 1888.

F. W. RUDLER, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association were accorded to the donors.

The following were elected Members of the Association:—Miss Benton; W. H. Dalton, F.G.S.; Rev. A. Johnson, M.A., F.G.S.; Gaetano Platania; Miss E. A. Smith.

The meeting then resolved itself into a Conversazione.

Among the chief objects exhibited were —

By MR. W. J. LEWIS ABBOTT, F.G.S., Specimens of various precious stones, in extensive suites of colours, forms, and cuttings; and pearls, recent and fossil, including the Cocoa-nut Pearl.

By PROF. J. F. BLAKE, M.A., F.G.S., Microscope with slides of Anglesey rocks.

By PROF. G. S. BOULGER, F.L.S., F.G.S., Editor, Specimens and slides of Ightham Stone; and *Capulus margarita*, sp. nov.

By MR. J. H. COTTON, A large series of casts of fossils.

By MESSRS. HENRY CROUCH, New petrological microscopes.

By Mr. James Fox, A fine series of Chalk Echinoderms, Fish and other fossils, etc., including—

Beryx radians.
Homonotus dorsalis.
Berycopsis elegans.
Tomognathus mordax.
Lamna subulata.
Oxyrhina heteromorpha.
Cimolichthys levesiensis.
Portheus gaultinus.
Enchodus halocyon.
Belanostomus cinctus.
Pachyrhizodus basalis.
Notidanus microdon.
Synechrodus.
Mosasaurus.
Protosphyræna ferox.
Otodus appendiculatus.
Corax falcatus.
Oxyrhina mantelli.
Ptychodus decurrens.
„ *polygyrus.*
„ *latissimus.*
Gyrodus angustus.
Bourgetiocrinus ellipticus.
Marsupites milleri.
Goniaster parkinsoni.
„ *hunteri.*
„ *uncatus.*
Astrogonium coombi.
Oreaster.
Cidaris perornata.
Cidaris clavigera.
„ *sceptrifera.*
„ *hirudo.*
„ *sub-vesiculosa.*
Cyphosoma konigi.
„ *corollare.*
Ananchytes pillula.
Discoidea dixoni.
Pecten quinquecostatus.
„ *beaveri.*
„ *nitidus.*
Spondylus spinosa.
„ *latus.*
Lima globosa.
„ *hooperi.*
Ostrea frons.
Rhynchonella plicatilis.
Serpula plexus.
„ *ampullacea.*
Parasmilia centralis.
„ *fittoni.*
Stephanophyllia bowerbanki.
Holostoma contingens.
Cyathina lævigata.
Pholadomya.
Scaphites æqualis.
Solarium.
Scalpellum.
Spongidæ.
Rolled flint and Quartz pebbles.

By Mr. W. B. Gibbs, F.R.A.S., Nummulitic limestone from Mokattam; and microscope with quartz sand.

By Mr. James R. Gregory, Specimens of the Russian diamantiferous meteorite and "Butterfly" twins of Calcite, etc.

By Mr. W. F. Gwinnell, F.G.S., Geological maps of the Forest of Dean, two inches to the mile, and of Gravesend, eight inches to the mile, prepared by the exhibitor; photographs and specimens

illustrative of the last Long Excursion, and of glacial action; Felspar crystals; specimen sheets of the exhibitor's 'Notes and Tables on Geology,' etc.

By Mr. Samuel Henson, Finely crystallized Witherite, Green Fluor, Epidote, Fahlerz, Rhabdophane, etc.

By Messrs. James How & Co., Microscopes with petrological slides, transparencies, and lantern showing petrological slides on diaphanic screen.

By Mr. H. M. Klaassen, F.G.S., Photograph and painting of the Aletsch Glacier and Merjelen See.

By Mr. James Love, F.R.A.S., Stereoscopic projections of crystals.

By Mr. Edward Lovett, Arrowheads in obsidian, hornstone, carnelian, jasper, etc.

By Mr. S. H. Needham, Gems, Minerals, and Fossils.

By Mr. E. T. Newton, F.G.S., Fossils from the St. Erth Crag.

By Mr. J. J. B. Ogle, Star-fish from the Chalk.

By Mr. F. W. Rudler, F.G.S., President, A collection of precious and ornamental stones.

By Messrs. James Swift & Sons, A new petrological microscope in which the concentric rotating stage is dispensed with.

By Messrs. Watson & Sons, two microscopes.

During the evening Mr. W. Whitaker, F.R.S., F.G.S., exhibited cores, and gave an account of the deep boring in progress at Stockwell.

ORDINARY MEETING.

Friday, December 7th, 1888.

F. W. Rudler, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association were accorded to the donors.

The following were elected Members of the Association:—B. Corcoran, G. Davey, Mrs. Corrie Grant, F. E. Lyne, J. R. McIlraith, M.A., LL.B.

The following Papers were then read:—

'On the Causes of Volcanic Action,' by J. Logan Lobley, F.G.S.

'Some Observations upon the Mode of Occurrence and Origin of Metalliferous Deposits,' by J. G. Goodchild, F.G.S.

There were exhibited:—By Prof. J. F. Blake, M.A., F.G.S., some rock-specimens from Vesuvius in illustration of his remarks on Mr. Lobley's paper; and by Mr. Goodchild, specimens in illustration of his paper.

ORDINARY MEETING.

Friday, January 4th, 1889.

F. W. Rudler, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library, which included a valuable series of geological works and maps, the bequest of the late W. H. Bartlett, F.G.S., were announced, and the thanks of the Association were accorded to the donors.

The following were elected Members of the Association:—F. P. Lane; F. M. Lavanchy; Miss A. Lee, B.A., B.Sc.; A. Le Grand; Miss E. Phipson; and J. Tenny.

Messrs. Horace W. Monckton, F.G.S., and Upfield Green were elected Auditors of the accounts for 1889.

The following Papers were then read:—

'On some Bagshot Pebble-Beds and Pebble-Gravel,' by Horace W. Monckton and R. S. Herries.

'On the Palæontology of Sturgeons,' by A. Smith Woodward.

Specimens were exhibited by the authors in illustration of their papers.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 1ST, 1889.

F. W. RUDLER, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The minutes of the previous Annual General Meeting were read and confirmed.

Messrs. H. M. Klaassen, F.G.S., and J. B. Ogle were appointed Scrutineers for the ballot.

The following Report of the Council was then read:—

The list of the Association on the 31st of December last showed its numbers to be as follows:—

Honorary Members	16
Ordinary Members:—	
a Life Members (Compounded)	129
b Old Country Members (5s. Annual Subscription) ...	14
c Other Members (10s. Annual Subscription) ...	365
Total	524

During the year 34 Members were elected. The Council regret that the Association lost five Members by death:—Mr. H. B. Armstrong, Mr. W. H. Bartlett, Rev. T. H. Browne, Mrs. Ogilvie, and Mr. S. Trickett.

Mr. W. H. Bartlett was a constant attendant at our excursions, and, despite his infirmity of lameness, was a most unflagging walker and the cheeriest of companions. His familiar presence has been missed during the past year, though his memory remains and will be preserved to us by the valuable bequest of his geological books and maps lately received.

In the Rev. T. H. Browne the Association loses one of its first Members.

The financial position of the Association continues to be satisfactory. The expenditure has been unusually heavy, having exceeded the ordinary receipts (*i.e.*, excluding life-composition fees) by about £18. This excess is more than accounted for by extra expenditure incurred in printing the 'Proceedings,' twice as many pages having been printed in 1888 as in 1887, and they are

GEOLOGISTS' ASSOCIATION.

Income and Expenditure for the Year ending 31st December, 1888.

Dr.	£	s.	d.
To Balance from last Account	82	5	8
„ Life Compositions	26	5	0
„ Admission Fees	16	0	0
„ Annual Subscriptions	170	15	0
„ Dividends on £691 4s. Nottingham Corporation Three per cent. Stock	20	4	4
„ Sale of Publications	6	15	6
„ Advertisements	6	8	9
	£328	14	3

Cr.	£	s.	d.
By Printing 'Proceedings'	125	7	11
„ „ Monthly Circulars	21	17	0
„ Illustrating 'Proceedings' and Circulars ...	7	13	10
„ Miscellaneous Printing...	12	12	0
„ Postages	39	5	0
„ Addressing	8	13	0
„ Library	7	1	0
„ Fire Insurance for 1889	1	17	6
„ Stationery	1	6	0
„ Attendance, Gas, &c., at Evening Meetings	11	15	0
„ Miscellaneous Expenses	0	9	0
„ Balance in Bank of England...	90	17	0
	£328	14	3

We have this day examined the Accounts of the Treasurer of the Geologists' Association, and we find the above Statement to be correct.

(Signed) HORACE W. MONCKTON, UPFIELD GREEN, } Auditors.

17th January, 1889.

now more nearly up to date than at the end of the previous year. If the two years are taken together it will be found that there is an increase of about £32 in the available balance. The Council recommend that 35 guineas received for life compositions since the last investment was made be invested, leaving a balance of just over £54 towards meeting expenditure to be incurred on extra publications in 1889.

Since our last Report six numbers of the 'Proceedings' have been issued, viz., Nos. 3-8 of Vol. x, containing in all 376 pp., illustrated by 1 plate and 33 cuts. We are indebted to Mr. A. Smith Woodward for the plate and to Mr. J. Allen Brown, the Rev. E. S. Dewick, and Mr. B. B. Woodward for cuts illustrating papers by them. No. 9, completing Vol. x, and No. 1 of Vol. xi, in which the 'Proceedings' and the 'Papers' will have distinct paginations, will be ready shortly; whilst the 'General Index' to the first decade of the 'Proceedings,' mentioned in our last report, is in preparation, and will be presented to all Members.

The task of editing the long projected 'Record of the Excursions of the Geologists' Association—1860 to 1884' has now been completed by Mr. Holmes, and decision as to its appearance virtually rests with the Members, since it must be published by subscription. As yet the number of names received (130) is not sufficient to justify its publication, at least double this number being required.

Many valuable additions to the Library, both by presentation and in exchange for our 'Proceedings,' have been made during the past year, including the generous bequest by the late W. H. Bartlett already referred to. The average number of volumes in circulation amongst the Members has been well maintained.

Your thanks are due to Mr. E. Litchfield, who has constantly assisted your Librarian on the nights of the evening meetings.

The following is a list of the Papers read at the evening meetings:—

'On the Occurrence of Gold in North Wales,' by T. A. Readwin, F.G.S.

'On the History and Work of the International Geological Congress,' by W. Topley, F.R.S., F.G.S., Assoc. Inst. C.E., of the Geological Survey of England and Wales.

'Note on the Pleistocene Land and Freshwater Mollusca from the Barnwell Gravels,' by B. B. Woodward, F.G.S.

'On the Evolution of the Cephalopoda,' by F. A. BATHER, B.A., F.G.S.

'On the Influence of Geology on the Early Settlements and Roads,' by F. J. BENNETT, F.G.S., of the Geological Survey of England and Wales.

'On the Discovery of Elephas primigenius associated with Flint Implements at Southall,' by J. ALLEN BROWN, F.G.S.

'On Palæozoic Arcidæ,' by J. LOGAN LOBLEY, F.G.S., &c.

'On Pterodactyls,' by E. T. NEWTON, F.G.S., F.Z.S., &c.

'The Natural History of Gypsum,' by J. G. GOODCHILD, F.G.S., of the Geological Survey of England and Wales.

'On the Rhætics and Lias of Glamorganshire' (with reference to the Long Excursion), by H. B. WOODWARD, F.G.S., of the Geological Survey of England and Wales.

'On the Geology of the Forest of Dean' (with reference to the Long Excursion), by E. WETHERED, F.G.S., F.C.S.

'On the Clays of Bedfordshire' (with reference to the Bedford Excursion), by A. C. G. CAMERON, of the Geological Survey of England and Wales.

'On the Causes of Volcanic Action,' by J. LOGAN LOBLEY, F.G.S., &c.

'Some Observations upon the Mode of Occurrence and Origin of Metalliferous Deposits,' by J. G. GOODCHILD, F.G.S., of the Geological Survey of England and Wales.

A conversazione was held on November 2nd and, in the course of the evening, Mr. W. Whitaker, F.R.S., gave a brief description of the Streatham boring.

Subjoined is a list of the Museums, Geological Collections, &c., visited during 1888 :—

British Museum (Natural History), on March 17th, when Dr. Woodward, F.R.S., the Keeper of the Geological Department, conducted the party through the Fossil Mammalian Gallery to the South-east Pavilion, where he gave a demonstration on the Edentata, Marsupialia, and Wingless Birds exhibited there.

British Museum (Natural History), on April 7th, when Mr. W. Carruthers, F.R.S., the Keeper of the Botanical Department, took the Members through his Gallery and gave an exposition of the 'Fossil Algæ.'

Leicester Museum, on May 19th, when Mr. Montague Brown, F.Z.S., explained the Collections to the party.

Reading Museum, on June 16th, over which Dr. Stevens conducted the party.

Bedford Museum, on July 21st.

Gloucester Museum, on August 7th, under the guidance of Mr. Gwinnell and Mr. Madan.

Cardiff Museum, on August 9th, when the Members who attended the Long Excursion were received by Mr. T. H. Thomas, Dr. C. T. Vachell, Prof. R. W. Atkinson, and Mr. J. Storrie, the Curator, and conducted over the building.

The following is a list of the Excursions made during the past year, detailed reports of which will be found in the number of the 'Proceedings' for November, 1888:—

To Southampton, on Easter Monday and Tuesday, April 2nd and 3rd, in association with the Hampshire Field Club, under the direction of W. Whitaker, F.R.S., F.G.S., and J. Starkie Gardner, F.G.S.

To Wimbledon and Putney, over the Wimbledon and Fulham Railway, on May 5th, under the direction of W. Topley, F.G.S., and Oswald M. Prouse, F.G.S.

To Charnwood Forest, on Whit-Monday and Tuesday, May 21st and 22nd, under the direction of the Rev. E. Hill, M.A., F.G.S., and J. D. Paul, F.G.S.

To Laindon Hills, Essex, on June 9th, in association with the Essex Field Club, under the direction of W. Whitaker, F.R.S., and W. Crouch, F.Z.S.

To Reading, on June 16th, under the direction of J. H. Blake, F.G.S., Assoc.M.Inst.C.E.

To Caterham, Godstone, Tilburstow, and Nutfield, on June 23rd, under the direction of Prof. G. S. Boulger, F.L.S., F.G.S.

To Rickmansworth, on June 30th, in association with the Hertfordshire Natural History Society, under the direction of John Hopkinson, F.L.S., F.G.S.

To Loampit Hill, Lewisham, and Westcombe Park, Greenwich, on July 7th, under the direction of T. V. Holmes, F.G.S.

To Bedford and Clapham, on Saturday, July 21st, in association with the Bedfordshire Archæological and Natural History Society, under the direction of A. C. G. Cameron.

To the Forest of Dean, Wye Valley, and South Wales, from August 6th to 11th, under the direction of the President; William Galloway, of Cardiff; W. F. Gwinnell, F.R.Met.S.; J. Storie, Curator of the Cardiff Museum; T. H. Thomas, R.C.A., President of the Cardiff Naturalists' Society; Dr. C. T. Vachell, of Cardiff; and E. Wethered, F.G.S., F.C.S., F.R.M.S., Hon. Sec. Cotteswold Naturalists' Field Club and Cheltenham Nat. Hist. Soc.

The thanks of the Association are especially due to the following gentlemen for assistance and hospitality on these Excursions: Mr. W. Whitaker, F.R.S.; Messrs. Lucas and Aird; Mr. Montague Browne, F.Z.S., Leicester; Dr. Stevens, Hon. Curator, Reading Museum; Mr. T. V. Holmes, F.G.S.; Mr A. C. G. Cameron, Bedford; Mr. J. Hawkins, Mayor of Bedford; Rev. Canon Haddock, Clapham (Beds.); the Very Rev. the Dean

of Winchester; the Very Rev. the Dean of Gloucester; his Grace the Bishop of Llandaff and Mrs. Lewis; the Very Rev. the Dean of Llandaff and Mrs. Vaughan; Rev. Canon Downing; Mr. W. C. Lucy, F.G.S., Gloucester; Mr. and Mrs. W. Colchester-Wemyss, Micheldean; Mr. T. H. Thomas, President, Dr. C. T. Vachell, Vice-President, and Prof. W. R. Atkinson, Hon. Sec., Cardiff Naturalists' Field Club; Mr. J. Storrie, Curator Cardiff Museum; Mr. Pettigrew and Mr. Galloway, Cardiff; Mr. J. Pyke Thompson, Penarth; Mr. Stephen Vivian, Llantrisaint; Mr. T. Forster Brown, Coleford, Forest of Dean; the Directors and Managers of the Lewis' Merthyn Colliery; the Directors and Managers of Harris' Navigation Pit; the Directors of the Taff Vale Railway Company.

Your thanks are also due to the Council of the Quekett Microscopical Club for the use of their lamps on the evening of our Conversazione.

During the past year the meetings of the Association have been held in different rooms of this building with the view of ascertaining whether one could be selected which offered greater facilities for hearing and seeing than did the Library, in which we formerly met.

Your thanks are due to the Council of University College, not merely for "housing" us, as they have now done for so many years past, but also for permitting us thus to select what it is hoped may prove more suitable quarters for our purpose, especially since permission has been accorded to place our bookcases in this room.

Mr. F. W. Rudler, having completed his term of office, retires this year from the chair, having more than fulfilled the expectations which were formed when he became President. The affairs of the Association have received his continuous and careful attention; nor did his zeal on their behalf flag for one moment last autumn despite the fact that, in conjunction with his predecessor, Mr. Topley, he was engaged in the arduous, and successfully-achieved, task of preparing for and carrying through the arrangements connected with the meeting of the International Geological Congress.

During his Presidentship, Mr. Rudler has paid the greatest attention to the excursions, of which he proved himself a most

successful organizer; indeed, during the past year nearly the whole charge devolved on him. Moreover, it is worthy of remark that never once has he been absent from any of the Association's meetings or excursions.

Finally, we are indebted to him for his valuable 'Summary of the Progress of Geology during the past Fifty Years,' which formed the theme of his discourse a little more than a year ago.

Your Council have much pleasure in proposing as his successor Mr. T. V. Holmes, F.G.S., to whom the Association is already so largely indebted for help and advice.

Mr. Holmes' practical acquaintance with geology in the field, coupled with his varied and extensive literary attainments, render him in every way a fitting occupant of the chair which your Council feel convinced he will fill to the satisfaction of the Members and the great advantage of the Association.

The adoption of the Report was proposed by Dr. Henry Woodward, F.R.S., seconded by Mr. W. F. Gwinnell, F.G.S., and carried unanimously.

The following Officers and Council for the year 1889 were then declared duly elected :—

President:

T. V. HOLMES, F.G.S.

Vice-Presidents:

Rev. Prof. T. G. Bonney, LL.D., F.R.S.
Prof. F. Meldola, F.R.S.
F. W. Rudler, F.G.S.
W. Topley, F.R.S., F.G.S.

Treasurer:

J. Hopkinson, F.L.S., F.G.S.

Secretaries:

J. Foulerton, M.D., F.G.S.
B. B. Woodward, F.G.S., F.R.M.S.

Editor:

Prof. G. S. Boulger, F.L.S., F.G.S

Librarian:

J. Bradford, F.G.S.

Twelve other Members of Council:

Prof. J. F. Blake, M.A., F.G.S.	H. W. Monckton, F.G.S.
Rev. E. S. Dewick, M.A., F.G.S.	Major-Gen. C. A. McMahon, F.G.S.
H. H French, F.G.S.	S. H. Needham, F.G.S.
W. B. Gibbs, F.R.A.S.	E. T. Newton, F.G.S.
H. Hicks, M.D., F.R.S., F.G.S.	Miss C. A. Raisin, B.Sc.
W. H. Hudleston, M.A., F.R.S., Sec.G.S.	A. S. Woodward, F.G.S.

The President then delivered his Address on 'Experimental Geology.'

ORDINARY MEETING.

Friday, February 1st, 1889.

T. V. Holmes, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous Ordinary Meeting were announced, and the thanks of the Association were accorded to the donors.

The following gentlemen were elected Members of the Association:—Grenville A. J. Cole, F.G.S. and H. Dewes, F.G.S.

There being no Paper the meeting then terminated.

EASTER EXCURSION, 1888.*

PRELIMINARY EXCURSION TO NEWBURY.

FRIDAY AND SATURDAY, MARCH 30TH AND 31ST.

Director: W. WHITAKER, F.R.S., F.G.S., assisted by F. J BENNETT, F.G.S.

(*Report by* R. S. HERRIES, F.G.S.)

Those of the party who had come down to Newbury on the previous day began the morning of Friday, March 30th, by a visit to the Shaw Kiln, about a mile and a half to the north-east. The two clay-pits here show very good sections of the junction of the Reading beds with the Chalk below and with the London Clay above, and attention was particularly drawn by the Director to the even character of the junction of the Reading beds with the Chalk, and to the fact that the top of the latter is perforated by long tubular holes filled with the green sand of the bottom-bed. This bottom-bed is very full of oyster-shells, and is of marine origin. Above it are light-coloured fresh-water sands, containing a clay band in which impressions of leaves have been found, and Mr. Starkie Gardner said that these were of the same species as those found at Reading. These sands are succeeded, upwards, by the Mottled Clays, and the junction with the London Clay is marked by a bed of flint pebbles, some of which are of great size and easily fractured. The London Clay is here only about 50 feet thick, there being a continual and marked diminution in its thickness as we proceed westwards.

The party then returned to Newbury, passing Shaw House, a stately brick mansion of the time of Queen Elizabeth, which was the head-quarters of King Charles I. during the second battle of Newbury, of which battle Mr. Bennett gave a very interesting account.

At Newbury the party was reinforced by those Members who had come down by the 9.5 train from London, and after a rest all set out on the road to Donnington, with the intention of proceeding northwards across Snelsmore Common to Bussock Camp. At

* No report of this Excursion was received before the publication of the Excursion Number for 1888.—ED.

Donnington Kiln, another junction-section of the London Clay and Reading beds was seen, though it is, unfortunately, somewhat obscured owing to the pit being no longer worked. Here, as at Shaw, a line of very large pebbles marks the junction between the two formations. On Snelsmore Common there is a gravel of a very pebbly nature, soon after inspecting which it came on to rain so heavily, that, after waiting for some time under the best shelter that could be found, it was decided to abandon the remainder of the programme, and return to Newbury. This was accordingly done, most of the party stopping on the way to inspect the ruins of Donnington Castle, which played an important part in the battle which has already been mentioned.

Had the persistent rain not put a stop to the day's proceedings, the party would have found Bussock Camp to be a square entrenchment, probably of Roman origin, and within it a deposit of flint pebbles about two feet thick capping the highest part of the hill. It is believed that Mr. Whitaker and Mr. Bennett were prepared to argue that this was a Bagshot pebble-bed, a proposition that would not have been allowed to pass unchallenged; and so the party were deprived of the pleasure of hearing one of those animated discussions for the promotion of which the Bagshot Sands seem to have been specially created. For a suggestion as to the probable age of this deposit, see a paper by H. W. Monckton and R. S. Herries "On some Bagshot Pebble-beds and Pebble Gravel" ('Proc. Geol. Assoc.,' Vol. xi, p. 22).

In the evening the party dined at the "Jack," and after dinner Mr. Bennett gave an interesting account of the Newbury Peat, and the proceedings terminated with a hearty vote of thanks which the President proposed to that gentleman for the trouble he had taken in connection with the visit.

On Saturday, the 31st, the party left Newbury by the 8.55 train for Highclere, sending their luggage to Winchester. From Highclere Station they first walked to a sand-pit (mapped as Lower Bagshot) near West Street, about half-a-mile to the south, where Mr. R. S. Herries explained that the sands there should probably be referred to the Upper Division of the Bagshot beds, as first suggested by Dr. Irving ('Q. J. G. S.' Vol. xliv, p. 178); and he gave as his reasons their position near the axis of a sharp syncline, the nature of the sands themselves, their freedom from false-bedding, and the presence in them of casts of marine shells,

of which he had found a considerable number on a previous visit. Mr. Starkie Gardner concurred, though Mr. Bennett did not appear to relish the task of drawing boundary-lines between the subdivisions of the Bagshot in this part of the country.

On the return to the railway, Mr. Whitaker made some remarks on the general structure of the country, in the course of which he pointed out that, owing to the high northerly dip of the Chalk here, about 30°, the whole thickness of the beds from the top of the London Clay to the base of the Chalk only occupied on the map a space of about half-a-mile. The Reading beds were at least 70 feet thick, and he observed that in nearly all cases where there was a high dip there was an unusual thickness of these beds. He also drew attention to the fact that with the high dip and consequent narrowness of the outcrop of the Chalk, that formation made a low ridge, whilst where the dip was low, and the outcrop broad, as was the case a little further south, it had a high escarpment.

The party then proceeded along the line in a southerly direction, first observing the junction of the Reading beds with the Chalk, well marked in the cutting by the occurrence of oysters and green-coated flints. A little further on, the Chalk Rock, which divides the Middle from the Upper Chalk, was seen. It is a remarkably hard bed, and contains fossils and many green nodules. The next cutting was in the Upper Greensand, which is brought up here by an anticlinal, and occupies a tract of country about five miles in length and about a mile and a half in breadth, known as the Kingsclere Inlier. Some fossils were obtained from this, and it was pointed out that the dip to the north was now much reduced, and a little further on, at Burghclere Station, this had become a slight dip to the south.

Here the party left the line, and after inspecting the interesting Norman and Early English Church, ascended Beacon Hill, a beautifully-shaped Chalk Hill, more than 800 feet high, and surmounted by a large and irregularly-shaped camp consisting of a double earthwork and ditch. A discussion took place as to the water-supply of the camp, and Mr. Whitaker and Mr. Bennett seemed to think that it might have been derived from dew-ponds, of which there was one on Ladle Hill, which, with its camp, was conspicuous a mile and a half to the east.

Having disposed of their luncheon, and sufficiently enjoyed the beautiful view, the party made the steep descent in somewhat

irregular order, and once more reached the railway. The dip was now a distinct southerly one, and the Melbourn Rock, which marks the division between the Lower and Middle Chalk, was seen. Further on, attention was directed to some tumuli, known as the Seven Barrows, and Mr. Bennett made some remarks as to the cause of their erection here, suggesting that it was owing to the fact that the Bourne rises at this spot, which led to a discussion on the origin of Bournes, which were said by the Director to be caused by the rising of the underground water until it reaches the surface and overflows, causing an overground stream. In the next cutting the Chalk Rock was again seen, and several fossils, especially some fine Gastropods, which are not common in the Chalk, were obtained. This brought the party to Litchfield Station, where they took the 2.45 train to Winchester, and repaired to the Black Swan. Later in the afternoon the Dean kindly conducted them over the Cathedral, and on the following day the old Hospital of St. Cross was visited, as well as some of the chalk-pits in the neighbourhood. On Monday morning the party joined the main body at Southampton.

EXCURSION TO SOUTHAMPTON.

EASTER MONDAY AND TUESDAY, APRIL 2ND AND 3RD, 1888.

(In conjunction with the Hampshire Field Club.)

Director: W. WHITAKER, F.R.S., F.G.S., assisted by J. STARKIE GARDNER, F.G.S.

(*Report by* R. S. HERRIES, F.G.S.)

Members left London on Monday, April 2nd, by the 8.5 train and at Winchester were joined by those who had taken part in the preliminary Excursion. At Southampton they deposited their luggage, and, being reinforced by a contingent of the Hampshire Field Club, continued their journey to Milton, a station on the new direct line to Bournemouth. Attention was called to the great difficulty the Company had met with in constructing this railway, owing to the remarkable spread of the embankments, by which field after field had been absorbed.

The party walked southwards about three miles to the coast

near Hordle House. Before descending to the shore the Director gave a short general account of the configuration of the district and pointed out the corresponding beds on the mainland and the Isle of Wight, on the one side compressed owing to the almost vertical dip into the small space of Alum Bay, on the other extending through the whole of Christchurch Bay, as far as the Chalk of the Isle of Purbeck. The party then descended, and after a halt for luncheon, walked westwards as far as the ravine known as Becton Bunny, Mr. Starkie Gardner explaining the beds and their various sub-divisions as they occurred, in accordance with the classification proposed and set out in detail in the paper, which he, in conjunction with Mr. H. Keeping and Mr. H. W. Monckton, had read on the previous Wednesday, before the Geological Society ('Q. J. G. S.,' Vol. xliv, p. 578).

The beds dip slightly to the east, and were therefore examined in descending order. The Lower Headon beds, which were first met with, are of fresh-water origin, and contain much lignite; also crocodilian and mammalian remains, *Paludina*, *Limnæa*, etc. In one place Mr. Gardner called attention to a singular interruption of the bedding where the "Leaf bed" and "Crocodile bed" are cut through, and replaced by a confused mass of clay and sand with drift wood, some of which is seen anchored vertically in the mud, being evidently snags in the channel of an old river. There is a similar old estuary-channel between Colwell and Totland Bays in the Isle of Wight. Below the Lower Headon are the Long Mead End beds, or Headon Hill Sands, which have unfortunately also been called Upper Bagshot Sands, a circumstance which has given rise to great confusion, owing to the fact that the same name has been given to a different bed in the London Basin. Mr. Gardner explained that the Upper Bagshot of the London Basin was probably the equivalent of the Lower Barton and upper part of the Bracklesham, while these Long Mead End beds were the very highest beds of the Barton, being classed, indeed, by many people with the Lower Headon. They were entirely unrepresented in the London Basin. They consist of about 20 feet of white sands with a layer of fossils in the upper part, a careful examination of which led the late Mr. Tawney ('Proc. Cambr. Phil. Soc.,' Vol. iv, Part III, p. 140), to class the sands rather with the Barton beds below than with the Headon beds above, an opinion in which Mr. Gardner concurred. The next beds

below are the Becton Bunny beds, and in them the fauna is entirely marine. Over the whole of these beds, and resting on each in turn, is a thick deposit of old river gravel which forms the upper part of the cliff nearly as far as Christchurch, when the whole of the beds are entirely cut off by the Avon river gravel. This old gravel contains flint weapons of the Palæolithic type, a series of which were exhibited by the Rev. H. Vandoorne.

The party made their way back from Becton Bunny to Milton Station, whence they returned about 6.30 to Southampton, the train being specially stopped for them through the kindness of the officials of the South Western Railway. At Southampton they fixed their headquarters at the South Western Hotel. While waiting for the train at Milton, the party inspected the collection of Barton fossils made by Mr. Daniel Flynn, of the coastguard station at Barton, who had accompanied the party, and most of the members enriched their collections by purchases more or less large from the beautiful selection of specimens which he exhibited.

On Tuesday, the 3rd, the party left Southampton by the 9.15 train for Milton, and, walking to the coast, resumed their examination of the beds at the point where they left off the day before. Below the Becton Bunny beds are the very fossiliferous Chama beds, so called from the great abundance of that curiously-shaped bivalve. Below, and forming the upper bed of the Middle Barton is a bed of hard stony slabs, made up mostly of comminuted fragments of shells, and called the Shell bed. These slabs are much sought after and carried away for building purposes, and to their removal the rapid erosion of the coast hereabouts is, no doubt, largely due, for by their resistance to the waves, these hard slabs would do much to retard the wasting process which is continually going on.

Below the Shell bed are the Middle Barton beds, which consist of 50 feet of drab sandy clay, with occasional bands of septaria. They occupy the broken slopes of the cliff as far as Chewton Bunny and yield a rich harvest of the most beautiful fossils to the collector, and the party were soon scattered over these slopes and busy filling their pockets as fast as they could. The Lower Barton beds, consisting of the Highcliff sands and underlying clays, occupy Highcliff, as the portion of the cliff west of Chewton Bunny is called, but they are so overgrown,

and covered by fallen material, that it is very difficult to examine them. At their base is a zone in which *Nummulites elegans* occurs, and a little below are the Bracklesham beds.

The remarkable change in the outlet of the Avon was pointed out. The natural mouth of this river is at Christchurch Harbour, just east of Hengistbury Head, but a bar of shingle having formed across it, the mouth was gradually driven further and further eastward, till the river flowing along the shore parallel with the cliff reached the sea under Highcliff House, about two miles off. Then in 1883, during a great storm this barrier was broken through, and now once more it flows out at Christchurch Harbour. The old course under the cliff is marked by a series of lagoons inside the great shingle bar.

The party were now met by Mr. Bellairs, who, by the kind permission of Lady Waterford, showed them over Highcliff House and grounds, both of which were much admired. After a vote of thanks to Mr. Bellairs, the party walked to Hinton Station, where the Company again kindly stopped the train, and the Members returned, some to Southampton, but most to their respective homes.

On Wednesday, the 4th, the Director accompanied a small party to Hinton, and the examination of the coast was resumed at Highcliff House. A search was made without success for the Nummulite bed. The Bracklesham beds form an escarpment 45 feet thick of compact white sand with carbonaceous matter, and in them occur two well-marked layers of pebbles, one at the top and the other eight feet from the base of the exposure. Soon afterwards the Tertiary beds are cut off vertically by a mass of gravel belonging to the Avon Valley, which occupies the coast as far as Christchurch Harbour. Here the river was crossed, and the walk was continued round Hengistbury Head, where the Bracklesham clays contain concretionary masses of ironstone and sandstone, the former of which was not very long ago worked for the sake of its iron. Further on, and underlying these clays, are white sands with a pebble-bed, and then darker, almost black, sands. After rounding the head, the party made its way to Christchurch and returned thence to Southampton.

While at Southampton an opportunity was given to the Members to visit the new dock works, and the Hartley Institute was visited under the able guidance of Mr. Shore, to whom the best thanks of the Association are due.

WORKS REFERRING TO THE HAMPSHIRE CLIFF-SECTIONS.

Geological Survey Map, Sheet 16.

WEBSTER.—"On a Freshwater Formation in Hordwell Cliff." 'Trans. Geol. Soc.,' ser. 2, Vol. i, pp. 90-94, pl. xii. (1822.)

LYELL.—"On the Freshwater Strata of Hordwell . . . . and Barton Cliff." 'Trans. Geol. Soc.,' ser. 2, Vol. ii, pp. 287-292, pl. xxx. (1827.)

WOOD.—". . . . Hordwell Cliff; with Observations upon the Geological Phenomena." 'Lond. Geol. Journ.,' pp. 1-7, 117-122. (1846, 1847.)

PRESTWICH.—'Quart. Journ. Geol. Soc.,' Vol. v. Refers to Barton, etc., pp. 43, 44. (1849.)

WRIGHT.—"A Stratigraphical Account of the Section at Hordwell, Beacon, and Barton Cliffs." 'Ann. Nat. Hist.,' ser. 2, Vol. vii, p. 433; reprinted in 'Proc. Cotteswold Club,' Vol. i, p. 120. (1851.)

MARCHIONESS OF HASTINGS.—"On the Tertiary Beds of Hordwell." 'Phil. Mag.,' ser. 4, Vol. vi, p. 1. (1853.)

PRESTWICH.—"On the Correlation of the Eocene Tertiaries of England, France, and Belgium." 'Quart. Journ. Geol. Soc.,' Vol. xiii. Parton pp. 107-110, 118-126. (1857.)

CODRINGTON.—"On the Superficial Deposits of the South of Hampshire." 'Quart. Journ. Geol. Soc.,' Vol. xxvi, p. 528. (1870.)

GARDNER.—'Quart. Journ. Geol. Soc.,' Vol. xxxv. Refers to Highcliff, etc., pp. 210-212. (1879.)

JUDD.—"On the Oligocene Strata of the Hampshire Basin." 'Quart. Journ. Geol. Soc.,' Vol. xxxvi, p. 137. Refers to Hordle, etc., pp. 170, 171. (1880.)

KEEPING and TAWNEY.—'Quart. Journ. Geol. Soc.,' Vol. xxxvii. Refer to Hordle, p. 107. (1881.) See also 'Proc. Camb. Phil. Soc.,' Vol. iv.

JUDD.—"On the . . . . Eocene and Oligocene Strata in the Hampshire Basin." 'Quart. Journ. Geol. Soc.,' Vol. xxxviii, p. 461. Hordle, pp. 472-475. (1882.)

TAWNEY and KEEPING.—"On the Section at Hordwell Cliffs." 'Quart. Journ. Geol. Soc.,' Vol. xxxix, pp. 566-574. (1883.)

See also KEEPING, ELWES, WOOD.—'Geol. Mag.,' 1883, pp. 428, 493, 527, 573.

For Newbury, etc., Sheet 12 of the Geological Survey Map (and the edge of Sheet 13).

ORDINARY MEETING.

FRIDAY, MARCH 1ST, 1889.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentleman was elected a Member of the Association:—W. H. Wesley.

The following paper was then read:—'The Geological History of Iron-Ores,' by W. H. HUDLESTON, F.R.S., Sec. G.S.

The paper was illustrated by lantern-slides and specimens.

VISIT TO THE NATURAL HISTORY MUSEUM, CROMWELL ROAD, DEPARTMENT OF BOTANY.

SATURDAY AFTERNOON, MARCH 16TH, 1889.

DEMONSTRATION ON FOSSIL FUNGI, LICHENS, MOSSES, ETC.,

By W. CARRUTHERS, Esq., F.R.S., Keeper of the Department.

(Report by THE EDITOR. *Revised by* MR. CARRUTHERS.*)*

The party assembled in one of the bays of the outer, or public, gallery of the Department. The Keeper began by referring to his Demonstration of last year on Fossil Algæ,* and pointing out that the division of the vegetable kingdom into the two groups of Cellular and Vascular plants was a most useful one for palæontological purposes. The first group rarely occurred as recognizable fossils. He proposed on this occasion to speak of the remaining Cellular plants—the Fungi, Lichens, and Mosses.

The Fungi might be looked upon as, in some respects, higher than the Algæ, since they live upon organic food, doing so either parasitically or saprophytically. Whilst British flowering plants may be reckoned as including some 1,400 species, our fungi number about 4,000, even allowing for cases, like that of *Puccinia graminis*, the Rust of Wheat, in which different stages in the life of one species have been described as independent plants belonging to several distinct genera. Fungi do not occur as parasites only on plants; since the disease known as ringworm is a well-known instance of a parasitic fungus attacking a living animal. As a group, the Fungi are characterized by the absence of chlorophyll. For the most part they are extremely perishable, and unlikely to be preserved as fossils. In fact, with very few exceptions, they are not known in a fossil state in beds earlier than the Tertiary. *Polyporites Bowmani*, from the Coal-Measures, proves to be the scale of a ganoid fish, and *Gyromyces Ammonis* is nothing but the tube of the worm *Spirorbis*. The exceptions are *Peronosporites antiquus*, a mould resembling that which causes the Potato disease, detected by the speaker in the interior of a decayed stem of *Lepidodendron;*

* 'Proc. Geol. Assoc.,' Vol. x., p. 468.

and certain amorphous bodies occurring in the shales of the Coal-Measure at Newcastle, which have been correctly described by Thomas Hancock as "sclerotia," compact masses, that is, of fungal mycelium, having the same function as the "ergot" on grasses.

Coming to Tertiary beds, it is chiefly as marks upon leaves of Oaks, Poplars, Maples, and other trees that fungi have been recognized. Some of the harder species have been found in Post-Tertiary peat. In investigating a fern-stem of Eocene age, found by one of the oldest Members of the Association, and named after him, *Osmundites Dowkeri*, Mr. Carruthers had found it penetrated with fungal mycelium. *Hydnum antiquum* has been found in the Œningen beds. The presence of Fungi, which have, however, perished, may be inferred, as the same beds have afforded remains of flies and beetles belonging to genera whose living representatives feed upon fungi.

Passing next to the consideration of the Lichens. There was no doubt, Mr. Carruthers said, that the modern interpretation of their structure, as consisting of combinations of fungal and algal elements living together, is morphologically correct; but for systematic purposes they must be treated as a distinct group. Being very perishable, it is not wonderful that they are known as fossils only in Tertiary strata, preserved in the coniferous resin found on the shores of the Baltic and familiar to us as amber. A number of species have been found belonging to existing genera, and including some species which cannot be separated from living forms.

The Muscineæ, the highest group of Cellular plants, include the Liverworts and the Mosses. Of the former group, two species of *Marchantia* and twelve species of *Jungermannia* have been identified in amber. The fossil Mosses are more numerous, but are also only known from Tertiary strata. Five species of *Dicranum*, three of *Polytrichum*, one of *Phascum*, and one of *Weissia* have been found in amber; eleven species of the larger *Hypnum* and two of *Fontinalis* have been described from the Tertiary rocks of Italy and South Germany; and a *Sphagnum* from the Hæmatite beds of Nassau.

The party were afterwards conducted into the inner room of the Department—the Students' Herbarium—where specimens of *Peronosporites* and of sclerotia were exhibited under microscopes, and some large recent sclerotia of *Mylitta australis*, used

as food in Tasmania, and smaller ones of *Peziza*, from Berkshire, were shown for comparison with the small ones on fossil leaves, such as those of *Sphæria*, from the Miocene.

After a cordial vote of thanks to Mr. Carruthers for his valuable Demonstration had been passed, on the proposition of the President, seconded by the Editor, the party dispersed.

ORDINARY MEETING.

FRIDAY, APRIL 5TH, 1889.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association :—A. E. Christy ; Miss M. George ; T. Howse, F.L.S.

The following paper was then read :—'A Visit to the Volcanoes of Italy,' by Professor J. F. BLAKE, M.A., F.G.S.

The paper was illustrated by lantern-slides and specimens.

VISIT TO THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS.

SATURDAY, APRIL 6TH, 1889.

Demonstration by Professor CHARLES STEWART, F.L.S., Curator of the Museum.

(*Report by* J. FOULERTON, M.D., F.G.S.)

A large number of Members met Prof. Stewart at the College at 2.30, and were conducted by him through the rooms, stopping for a short time at one or other of the many specimens contained in them, to listen to a short account of some characteristic feature exemplified by the particular specimen under consideration.

There was no attempt at methodical arrangement of any kind, but we all felt when the demonstration was finished that we had had a very interesting and profitable visit of two hours under the Professor's guidance.

A few illustrations will serve to convey a general idea of how the demonstration was conducted.

Infusoria.—The lowest forms consist of but one cell, which per forms all the functions of the animal, but the higher forms consis of several cells joined together, to form, as it were, a society, i which the different cells have different functions ; some, filled wit air, are used as floats, others digest the food for the whol organism, others perform the function of reproduction, others pro pel the organism through the water, etc., etc. The *Physalia*, o Portuguese Man-of-War from the Gulf Stream, for instance, has bladder for a float, long threads to catch prey, some cells to diges the food, others for the purpose of reproduction.

Attention was directed to the fine collection of human skulls and of the peculiar habits of many races, as exemplified by thei skulls. We were told how the Irish Giant, knowing that Hunte wanted his skeleton for the Museum, had left special direction and a considerable sum of money to have his body after deat thrown into mid-Irish Channel ; and so it was, but somehow— Jonah-wise or otherwise—his skeleton found its way to the Museum where it is looked up to by all who visit it, except by the Russia Giant, who was some inches taller.

An *Echinus* living outside the reef where the waves ar powerful, was seen to have short spines almost like a pavement just enough to hold on to the rocks, whilst those living in th tranquil waters inside the reef had long spines.

Our attention was next directed to the skeleton of the Greenlan Whale, suspended from the roof. The short fore limbs are use as paddles for steering, whilst the tail is the propelling orgar The hind limbs are very rudimentary, and embedded in the flesh so that they do not appear in the living animal ; but they sho that it was descended from an ancestor with hind limbs. Th head is very large, with a small brain-cavity. The large mout and jaw take in great quantities of water, which is passed ou through the filtering-apparatus formed by the "whalebone," leavin behind the small animals on which the whale feeds. To swallo these would be a difficult operation for air-breathing anima generally, and cause a constant feeling of choking ; but in th whale the œsophagus and air-passages are separate from on another. A similar arrangement of these passages exists in th young kangaroo, which would also be liable to be choked whil milk was being injected into its mouth by muscles which press th mammary gland of the mother when the young in the pouch

attached to the nipple and too weak to suck. The ossicles of the ear in air-breathing animals are usually separate, moveable, and jointed to one another, but in the whale they are all united. Rorquals measuring from 80 to 100 feet in length are often stranded on our coasts. The Sperm-whale, which feeds on cuttle-fish, squids, etc., has teeth, not whalebone. The *Xiphias*, or Sword-fish, has a very powerful tail, and rushes with great force at whales and other animals, driving its sword into their bodies. It has been known to pierce the copper sheeting of a ship's bottom and penetrate 13ft. of teak at one thrust.

The Paper Nautilus or Argonaut (*Argonauta*). What were supposed to be the sails of the argonaut are really two flattened arms, the function of which is to secrete the shell which protects the eggs.

The structure and function of the limbs of animals, of which there is a fine collection of the skeletons in the Museum, were explained, showing how they were modified to suit the habits of the animal; those living on marshy ground, like the early and now extinct progenitors of the horse, having a broad foot with spreading toes, whilst the horse of the present time, living on dry, solid ground, has all these toes fused together.

The great size of the elephant's skull was pointed out, not that the brain is large, for the cavity which contains it is small, but to give more room and leverage for the powerful muscles of the trunk. But this large skull is comparatively light, consisting for the most part of a honeycombed structure of great thickness between an outer and an inner shell of more solid bone.

The skeleton of the *Lophius*, or Angler-fish, which catches its prey whilst resting quietly at the bottom of the water with its mouth open, into which the prey enters, has an exceedingly small brain-cavity, being apparently sufficient for the brain of an animal which exercises so little either of cunning or muscular effort in obtaining its food.

The beautiful models of *Pterosauria*, with the greatly elongated bones of the hand, particularly the little finger for the support of the membrane which serves the purpose of the wing, were pointed out.

We were shown the egg of the extinct *Dinornis* of New Zealand; and also that of the *Epyornis* of Madagascar, also an extinct bird, the egg of which, we were told, would hold sixteen ostrich's eggs.

These and other so-called wingless birds—their rudimentary wings being useless for flight—probably lost the use of these organs from living where they had no enemies from which to fly, thereby escaping the dangers incident to flight; so that those that could not fly would have better chances of living than those that could.

These examples will serve to illustrate the nature of the very pleasant and instructive meeting we had at the College, for which the President proposed a vote of thanks to Prof. Stewart, which was cordially responded to. The party then broke up, but still continued for some time longer to inspect the specimens.

EASTER EXCURSION.

PRELIMINARY EXCURSION TO LYME REGIS.

APRIL 18TH TO 22ND, 1889.

Director: HORACE B. WOODWARD, F.G.S., of the Geological Survey of England and Wales.

(*Report by* THE DIRECTOR.)

Hardly any place in the British Isles is richer in features of geological interest than Lyme Regis; yet, hitherto, the Association had paid it no visit. On two occasions when Excursions had been arranged in the neighbourhood, the Members had come within a walking distance of the town. Thus, in 1871, under the guidance of Professor Buckman and Mr. Lobley, some Members went from Yeovil to Seaton and examined the cliffs for a short distance eastwards.* Again, in 1885, when your present Director had the honour of conducting a party from Bridport, the Members examined the cliff-sections from Burton Bradstock to Eype, east of Thorncombe Beacon.† The trip now undertaken served to complete the examination of this portion of our coast.

April 18th.—The Members assembled at the Waterloo Station in time for the 2.40 p.m. train on Thursday, and journeying as far as Axminster, arrived at eight o'clock, about an hour after the appointed time. A break and an omnibus, each with three horses, awaited the party, and as "the shades of night were falling fast,"

* 'Proc. Geol. Assoc.,' Vol. ii, p. 250.
† *Ibid.*, Vol. ix, p. 200.

an immediate start was made. Proceeding into the little town of Axminster, and beneath an archway through the yard of the George Inn, the vehicles were driven at a rapid rate through the narrow street that leads into the Lyme road. It seemed like a revival of old coaching times, and as the foremost carriage was driven full gallop down the first hill, the Director mildly inquired if no breaks were used in these parts. "Yes, surely," answered the driver. "You used no break coming down that hill." "That *worn't* a hill," was the somewhat gruff reply. Subsequent experience proved there were many far steeper hills, and especially the final descent to the Three Cups Hotel, which the Members reached safely soon after nine o'clock.

Lyme Regis lies between two spurs of the straggling Chalk and Upper Greensand outliers that serve to connect the Blackdown Hills of Devonshire with the Dorsetshire Downs. The hills on either side of the town rise to elevations of about 450 or 500 feet, and the valley is drained by the Lim or Lime, from which Lyme Regis derives a part of its name. Dating from about the year 900, Lyme became a town of some importance in the reign of Henry III., when it was known as Nether-lym supra mare, in distinction from Up-lym (Uplyme). In the reign of Edward I. the manor came to the crown, and as the King's demesne, the town assumed its present name.

In the course of the evening, after a substantial repast, the Director read some notes on the history and geological associations of the neighbourhood, remarking that to George Roberts, justly named "The Historian of Lyme Regis," we are indebted for most of the facts connected with the history of the parish.*

For at least 100 years the fossil treasures of the cliff have been sought after. W. G. Maton,† who travelled through the district in 1794 and 1796, mentions that "All curious productions of this nature are diligently collected by a man living at Charmouth, who is generally known throughout the county by the name of the Curi-man." Roberts informs us that this man sold his ammonites, etc, to the passengers of the coaches. His real name was Lock, though he was also known as Captain Cury, from his trade in

* See G. Roberts's 'History and Antiquities of the Borough of Lyme Regis and Charmouth,' 1834, pp. 286, etc.

† 'Observations relative chiefly to the Natural History, etc., of the Western Counties of England,' 2 Vols., 8vo., Salisbury, 1797. See Vol. i pp. 75-76.

"curiosities." Doubtless, he was one of the earliest fossil-collectors. Others who attained some local notoriety succeeded him, but it is to a lady that geologists are chiefly indebted for the early discovery of some of the large Saurian remains for which Lyme Regis is famous. Mary Anning, the daughter of Richard Anning, a cabinet-maker at Lyme Regis, was born in 1799. Her father, who had been also a vendor of fossils, died in 1810, and from that date Mary Anning devoted herself to the collection and sale of these objects. In 1811 she discovered bones of a "crocodile" projecting from one of the ledges of lias. Obtaining aid, the remains were exhumed, and the specimen was afterwards described by Sir Everard Home, under the name *Proteo-saurus*. One of the original plates illustrating this fossil was exhibited by the Director; but the name *Ichthyosaurus* (given by Koenig in 1814), having priority, is the name adopted. In 1821 Mary Anning obtained remains of another new Saurian, the *Plesiosaurus;* and in 1828 she obtained (for the first time in this country) the Pterodactyl, of which the species is now known as *Dimorphodon macronyx*.* As remarked by De la Beche, this enthusiastic collector exhibited great talent in developing the remains of Saurians. She died in 1847.†

Among the celebrities connected with Lyme Regis, we must not omit the name of Thomas Hawkins. He laboured for some time in collecting the Saurian remains both at Lyme Regis and at Street, near Glastonbury. In 1834 he published a large folio work, entitled 'Memoirs of Ichthyosauri and Plesiosauri, extinct monsters of the Ancient Earth.'‡ The illustrations were good, but the names applied to the animals were strange. Thus we have *Ichthyosaurus chirostrongulostinus* and *I. chiroparameteostinus;* names that, happily, have not been adopted. Hawkins also published another book,§ which the Members had the opportunity of inspecting at Rousdon. In this work the same plates were reproduced, but the letter-press is full of fanciful and mystical allusions. Many of his specimens are now in the British Museum, their apparently perfect condition having been produced by skilful restoration.

* Conybeare, Buckland, 'Bridgewater Treatise,' Vol. i, p. 203.

† 'Phil. Trans,' Vol. civ, p. 571; Vol. cvi, p. 318; Vol. cviii, p. 24; Vol. cix, pp. 209-212; and Vol. cx, p. 159.

‡ See De la Beche, Address Geol. Soc., 1848.

§ 'The Book of the Great Sea-Dragons, Ichthyosauri and Plesiosauri,' fol., 1840.

Mention should also be made of the late J. W. Marder, who was instrumental in obtaining remains of a second species of Pterodactyl, named *Pterodactylus Marderi*, as well as several new species of Fishes and Crustacea, described by Sir P. Egerton and Dr. H. Woodward.

Truly science owes much to those who devote themselves to collecting, and yet Lyme Regis never possessed for long a resident geologist who has been loth to part with his or her treasures.

Of others associated with the geology of Lyme Regis, we count several of the old masters—Buckland, Conybeare, and De la Beche.

In one sense Buckland was most intimately connected with the district, for he was born at Axminster, in 1784. His father was Rector of West Chelborough in Dorset, as well as of Templeton and Trusham in Devon. The son, when a child, often visited the Lias quarries near Axminster, collecting fossils which thus early excited his attention.*

Conybeare, who was born in London, in 1787, was appointed Vicar of Axminster in 1836, and held this office until 1845, when he was made Dean of Llandaff.

De la Beche, born also in London, in 1796, resided, when a youth, for several years at Charmouth and afterwards at Lyme Regis. Buckland first met him at the Assembly Rooms at Lyme Regis. These three geologists were much associated in their work, and while the stratigraphical geology of the district was mainly worked out by De la Beche, the organic remains, and especially the Saurians, were the subject of much study by Conybeare and Buckland, who also contributed a graphic account of the great Landslip.

No wonder "the southern shores of England soon became classic ground for the geological student."† The first maps issued by the Geological Survey, which had been established by De la Beche, included the country near Lyme Regis, embraced in Sheets 21 and 22 ; and these were for the most part the work of the founder. The adjoining Sheets 17 and 18 were surveyed by H. W. Bristow, and published in 1850.‡

* 'Reliquiæ Diluvianæ,' p. 242 ; "Geology and Mineralogy," 'Bridgewater Treatise,' Ed. 3, 1858.

† 'Obituary notice of De la Beche,' by W. J. Hamilton, Address Geol. Soc., 1856.

‡ Re-surveys of the country around Lyme Regis were made in 1873-74, by Clement Reid and H. B. W., but the new editions of the maps have not yet been issued.

Of others who have lived and laboured in the neighbourhood of Lyme Regis mention will subsequently be made.

April 19th.—Early on the Friday morning the Members started for Pinhay (or Pinney) Bay, along the footpath beneath Ware Cliffs. In the course of the walk a fine view was seen of the cliffs towards Golden Cap. The most striking feature in the geology here is the unconformable overlap or overstep of the Cretaceous rocks. In the higher grounds at Lyme Regis we see the Chalk and Upper Greensand resting on the Lower Lias; further west they repose on the Rhætic Beds and New Red Marl; while eastwards the Cretaceous rocks overstep in succession the Middle and Upper Lias, and the several divisions of the Oolites.

Proceeding along a tortuous path, amid fallen masses of Chalk and Greensand, and banks decorated with primroses, the Members arrived at the Pinhay ravine, and after a rough and somewhat muddy descent by the watercourse, reached the shore. The ravine itself coincides with a fault that throws down the limestones of the Lower Lias some feet on the west. Eastwards there appears the White Lias, dipping in the same direction, and covered by a thick mass of Blue Lias limestones. The section was described many years ago by De la Beche.* The full thickness of the White Lias is about 25 feet, but the base is not here seen.† The rock is remarkable for containing many "pebble-like concretions" which stand out in relief on its weathered faces. These lumps are composed of hard white or pale grey limestone, very similar to the matrix; and the following explanation had been suggested by Mr. A. Geikie, when on a visit to the coast in 1885: the calcareous mud may, during the accumulation of the strata, have been from time to time exposed to the sun's rays, so that films of mud might have curled up, and these, if subsequently rolled by an incoming tide, would be shaped into the lumps which form so conspicuous a feature in the rock.

Fossils are not readily obtained here, but they may be procured from exposures further west, and also in the quarries at Uplyme. The same remarks apply to the succeeding beds of Lower Lias limestone, which represent the "Ostrea-beds," and the zone of *Ammonites planorbis*. These yield *Ostrea liassica*, *Modiola minima*, and *Pleuromya crocombeia*. The fact is the beds are not very

* See references, p. xxviii *supra*.
† See Wright, 'Geol. Mag,' 1864, p. 290.

accessible, and they are not here worked for economic purposes. Moreover, the geologist in examining the cliffs is not free from danger, as pieces of rock occasionally fall, while attention must be paid to the state of the tide both along these "West Cliffs" and in those known as the "Church Cliffs," east of Lyme Regis.

The "*Planorbis*-beds" are not exposed far eastward of Pinney Bay, for these beds gradually descend to the shore, and do not rise again with the higher beds of limestone above the sea-level. The mass of the limestones, or "Blue Lias," which represent also the zones of *Ammonites angulatus* and *A. bucklandi*, attain altogether a thickness of about 80 feet, undulating a little in the West Cliff, descending to the sea-level below the town, and rising again (excepting the "*Planorbis*-beds") in the Church Cliffs on the east.

Spines of Urchins (*Cidaris* and *Hemipedina*) were noted by Dr. Wright in the clays above the White Lias east of Pinhay Bay, but they were only to be seen on the rocks exposed at low-water during spring-tides.*

Proceeding eastwards higher and higher, beds of limestone came into view, and layers containing *Rhynchonella variabilis*, *Gryphæa arcuata* (*incurva*), and one or two specimens of *Ammonites angulatus* were observed. Further on the stone is extensively worked for the Lime and Cement works, and each layer has its particular name known to the workmen.

Fine specimens of *Ammonites charmassei* may sometimes be obtained; also *Ammonites bucklandi*, *Nautilus striatus*, *Lima gigantea*, etc.

Lyme Regis is celebrated for its hydraulic cement, but De la Beche remarks that when Smeaton built the Eddystone lighthouse he sent to Aberthaw, in Glamorganshire, for the Lias lime, whereas if geological knowledge had then been available he might have procured it from Dorsetshire.† The bands of limestone are employed at the kilns for making "Blue Lias" lime and hydraulic cement, furnishing material for concrete foundations, brickwork, stucco, etc. Much material is also sent away at times in the raw state. Above the main mass of limestones there are also some layers of "Cement-stone," whose composition is naturally best suited for the preparation of cement.

* 'Quart. Journ. Geol. Soc.,' Vol. xvi, p. 397. In this paper Dr. Wright did not clearly distinguish the White Lias from the Lower Lias with *Ammonites planorbis*.

† 'Report on the Geology of Cornwall,' etc., p. 507.

On leaving the West Cliff a halt was made at Lyme Cobb for the purpose of lunch. The Cobb itself is said to date from the time of Edward I. as a construction to form a harbour of refuge; but it has many times been damaged or destroyed, and in its present form, although belonging in part to the fourteenth century, the main portion was reconstructed and completed in 1826. This was necessary after a great storm in November, 1824. The damage arose through the tide being checked by a furious gale from the S.S.E., the wind then veered to S. and S.W., and drove the heaped-up waters on to the coast.

The Cobb is built of "Cow-stones" from the Upper Greensand, with a walling of Portland "roach." Its name is said to be involved in mystery, some suggesting that the Cow-stones or cobbles may have originated it. Mr. Klaassen, however, assured us that the name Cob (or *Cop*) simply meant a point or headland.*

Proceeding along the promenade to the east, and through the town to the Gun Cliff, the Members passed Mrs. Dollin's famous fossil shop, the door of which stood invitingly open. A hurried glance was taken at the many specimens presented to view, and a promise was made to return to this emporium.

The Members now descended to the beach below the Church Cliffs, near the edge of which stands the parish church, whose churchyard has been to some extent curtailed. Attention was now directed to the great destruction of the cliffs at various points along the coast, caused mainly by gradual crumbling and landslips, while the sea has cleared away the fallen masses. George Roberts mentions that in 30 years, between 1803 and 1834, ninety feet in breadth of the Church Cliffs were lost, while a lane that led to Charmouth has for the most part slipped away to sea. But in this case man has not been free from blame, for Roberts mentions that "thousands of tons of limestone, the very ledges round our shore," have been shipped off, and he feelingly remarks that "a ledge, within a few feet of the eastern jetty, has actually been partly broken up, and the Table-rock and Horse-pond, names familiar to the natives of Lyme, and which bring fond recollections and associations of youth, are no more."†

* Isaac Taylor notes *Cop* (Saxon), a head. 'Words and Places,' Ed. 6, p. 326.

† 'History, etc., of Lyme Regis,' pp. 214, etc. See also "Report on Erosion of Sea-coasts, Axmouth to Eype," by H. B. W., 'Brit. Assoc.' for 1885.

Taking advantage of a point that afforded a good general view of the beds exposed in Black Ven, it was remarked that, while the cliff scenery in Yorkshire is grander than that in Dorsetshire, yet our south coast has the advantage of presenting the beds in clearer sequence, interrupted only by an occasional fault whose throw can be estimated with little difficulty. No better place probably in Europe exists for the study of the organic remains of the Lias in the successive groups known as "Zones."

The first detailed account of the Lias was given by De la Beche, who, adopting the nomenclature of William Smith and Conybeare, divided the beds as follows*:—

		Modern Grouping.
Upper Lias Marls	Clays with *Ammonites margaritatus*, etc.	Middle Lias (in part).
	Belemnite Beds, etc.	Lower Lias.
Lias Limestones	Blue Lias White Lias	
Lower Lias Marls	Black Shales Grey Marls	Rhætic Beds.

The beds now presented to view comprised nearly the whole of the Lower Lias, with the exception of the zone of the *Ammonites planorbis* at the base, and that of *A. capricornus* and *A. henleyi* at the top.

In the Church Cliffs we have only the upper portion of the "Blue Lias" presented to our view. This represents the zone of *A. angulatus* (in part) and that of *A. bucklandi*. Still higher is a bed of shale surmounted by a conspicuous band of hard grey marl, known as the "Table Ledge," which descends to the beach at the foot of Black Ven, and if we include this with the limestones below we have altogether a group about 105 feet in thickness, that represents the zones of *A. planorbis*, *A. angulatus*, *A. bucklandi*, and *A. turneri*. From a stratigraphical point of view this is a fairly convenient division here and elsewhere in the country, for it includes the main mass of the Lower Lias limestones.

The beds above comprise a series of dark and often pyritic shales, with bands of limestone and cement-stone. These beds constitute the dark beds in the lower part of Black Ven, and no doubt gave rise to its name. They attain a thickness of about 190 feet, and include the zones of *Ammonites obtusus*, *A. oxynotus*, and *A. raricostatus*.

* 'Trans. Geol. Soc.,' Ser. 2, Vol. ii, pp. 21-30. See also Ser. 2, Vol. i, pp. 40-47, and Plate VIII.

Still higher there is a well-marked band of pale grey marl, with indurated bands of pale marly limestone, known as the "Belemnite beds," which attain a thickness of about 80 feet. They are well shown not only in Black Ven, but again east of Charmouth, in the cliffs of Stonebarrow and Westhay, where they gradually descend towards the sea-level. A fault in the Charmouth valley, and another further east, has somewhat shifted their position.

These beds yield Belemnites in abundance, but otherwise are not very fossiliferous except towards the upper part. They represent the zones of *Ammonites armatus*, *A. jamesoni*, and *A. ibex*. At Black Ven, and again at Stonebarrow, we can in places find still higher beds (Green Ammonite beds), but these are better seen in the cliffs of Golden Cap. We have thus in sequence the following divisions of the Lower Lias :—

	Feet.
Green Ammonite Beds	105
Belemnite Beds	80
Dark Shales	190
Limestones and Shales	105
	480

The leading fossils of these beds are well known through the researches of Dr. Wright, Mr. E. C. H. Day, aided by the local fossil-collectors, Samuel Clark and the late Robert Hunter, of Charmouth. Remains of Saurians occur in the limestones, but more abundantly in the dark shales and cement-stones of Black Ven. About eight species of *Ichthyosaurus*, seven of *Plesiosaurus*, two Pterodactyls, and one Deinosaur (*Scelidosaurus*) have been recorded.* In these beds also were found the Coprolites originally described by Buckland.†

Remains of Fishes are also abundant, although their horizons are not so well known. They include species of *Acrodus* ("fossil leeches"), *Hybodus*, *Eugnathus*, *Lepidotus*, *Æchmodus*, and *Pholidophorus*, many of which occur in the zone of *Ammonites obtusus*.

Among Crustacea we find species of *Eryon*, *Æger*, *Glyphea*, and *Scapheus*. Echinoderms, Corals, and Polyzoa are not abundant; of the first-named *Pentacrinus* is found at various horizons, but the most noteworthy form is the *Extracrinus briareus*, of which

* J. C. Mansell-Plydell, "Fossil Reptiles of Dorset," 'Proc. Dorset Nat. Hist. Club,' Vol. ix, p. 1. E. T. Newton, 'Proc. Geol. Assoc.,' Vol. x, p. 406.

† 'Trans. Geol. Soc.,' Ser. 2, Vol. iii, p. 223.

fine examples, generally coated or replaced by pyrites, are found in the zone of *A. obtusus*. From the fact of this organism being often associated with lignite, Buckland expressed the opinion that the creatures had attached themselves in large groups to masses of floating wood.*

Of Belemnites and allied forms, we may note the *Belemnosepia* (or *Geoteuthis*) described by Buckland in 1836.† Ten years previously he had obtained specimens exhibiting remnants of fossil ink, samples of which were submitted to Sir Francis Chantrey, who had a drawing prepared with the material. The sepia was pronounced to be of excellent quality. Remains of *Xiphoteuthis* have also been obtained, and Professor Huxley has described two species of Belemnites—*B. elongatus* and *B. paxillosus*—with the ink-bags preserved.‡ *B. elongatus* was obtained from the zone of *Ammonites obtusus*.

Among plant-remains, *Araucarites* and *Otopteris* have been recorded.

The successive assemblages of organic remains are more marked by the Mollusca, and especially the Ammonites. As a rule the vertical range of the Ammonites is more restricted than that of other forms of life; hence the beds have been divided into zones, of which one characteristic and abundant species is chosen as an index. It must, however, be borne in mind that these divisions are artificial. The index Ammonite may not be found in its zone; it may range above and below it, while the assemblage of fossils that constitutes the zone is liable to vary in different places, for each species may have a different vertical and geographical range.

Therefore, while there is no doubt that here and there the zones become interblended, yet the general succession of the assemblages of species, and of the relative position of the zonal Ammonites is fairly well marked throughout the country. It may be difficult anywhere to say precisely where one zone ends and another begins, for throughout the Lias the lithological changes are gradual, and in the Lower Lias the "Bucklandi-beds" are not always represented by a thick mass of limestones. In the higher beds we have the marked changes in the Ammonite fauna, without any lithological changes to account for the modification of the forms of life. Nor

* 'Bridgewater Treatise,' 1836, p. 437.
† *Ibid.*, p. 305.
‡ "Monograph on the Belemnitidæ," 'Geol. Survey,' 1864.

do we find, as a rule, that the successive species of Ammonites are modifications of those that immediately preceded. The Director suggested that the changes in the assemblages of fossils might have coincided with certain movements of depression which did not affect the character of the sediment deposited, while favouring the incursion of different forms of life.

The Lower Lias limestones, as well as the shales, were mainly sedimentary, being to a large extent mechanically derived from old lands formed of Devonian and Carboniferous rocks. Perhaps a part of Cornwall and Devon, and portions of what is now Wales, may have yielded material, while even Ireland in those days may to some extent have been ground down.

With regard to the Ammonites of the Lias, the Director pointed out that many species figured by Sowerby were originally obtained from Lyme Regis and the neighbourhood. Among these was *A. bechei* (named after De la Beche), *A. birchii* (after Colonel Birch, a great frequenter of Lyme), *A. brookii* (after H. J. Brooke), *A. davoei* (after Sir H. Davey), *A. henleyi* (after H. H. Henley, the Lord of the Manor), and *A. loscombi* (after C. W. Loscombe), *A. fimbriatus*, *A. latæcosta*, *A. stellaris*, and *A. striatus*.

One species which had caused some perplexity to Mr. E. T. Newton and himself was *A. turneri*. The type was obtained from the Drift of Norfolk, and named after Dawson Turner, of Yarmouth. There is some doubt whether this species has actually been obtained at Lyme Regis. *A. semicostatus* is far more prevalent throughout the country on the horizon marked as that of *A. turneri*, and it occurs at Lyme Regis. Among other forms more or less closely allied are *A. brookii* and *A. bonnardi*.

Examples of all the zonal species were exhibited by the Director, who pointed to the positions of these and other leading fossils in the cliffs, and received unexpected confirmation from a sea-faring spectator, who now and again exclaimed, "That's right," "That's quite right!" The Director remarked that it was desirable to distinguish between zones and fossil-beds. In certain places we have "Gryphæa-beds," "Cardinia-beds," as well as "Fish- and Insect-beds," but these merely indicate the local preservation of certain forms of life.

In the zone of *Ammonites obtusus*, which lies above the "Table Bed," we find *Ammonites brookii*, *A. birchii*, and *A. stellaris*. Occasionally we find masses of limestone full of small Ammonites

(*A. obtusus* and *A. planicosta*), constituting a kind of Ammonite Marble, like the famous rock of Marston Magna, near Yeovil. *Belemnites acutus* is occasionally found, but these fossils, so very rare in lower beds, do not come on abundantly until we reach higher stages.

Ammonites oxynotus, and the local variety (*A. lymensis*) come on above. In the uppermost portion of the dark shales we find the "Metal-bed," with much iron-pyrites, and *A. raricostatus*; also *A. subplanicosta* and *A. densinodus*, specimens of which are cut and polished for brooches. *A. armatus* likewise is found in the upper portions of this division. We cannot fix precise limits for these zones, but the particular layers in which the species occur may be found with care and patience, especially with the aid of one of the local fossil-collectors.

Iron-pyrites was formerly collected for the manufacture of sulphuric acid. Its decomposition has caused some "spontaneous combustion" in the *débris* at the foot of the cliffs, and it is on record that in 1751 the cliffs near Charmouth began to smoke, and soon after to burn with a visible flame.

The Members now reached the foot of Black Ven, and having obtained the services of a local guide, they commenced to ascend the cliff. The hill rises to a height of 450 feet in places, and constant slips and changes in the cliffs render guidance advisable; indeed, the path proved to be treacherous in places, and some Members sank ankle deep in Lias mud. On attaining the level of the Belemnite beds only the more adventurous (including several ladies) clambered up higher to make acquaintance with the Gault, which here rests directly on the Lias.

Fitton first mentioned the occurrence of Gault fossils at this locality,* and in 1865 several species were recorded by the Geological Survey.† To Mr. C. E. De Rance, however, we are indebted for a more particular account of the extension of this formation, and his observations were a few years later supplemented by details furnished by the late Rev. W. Downes.‡

At the base of the deposit there is a layer of "grit," noted by

* 'Trans. Geol. Soc.,' Ser. 2, Vol. iv, p. 233.

† T. H. Huxley and R. Etheridge, "Catalogue of Fossils," 'Geol. Survey,' pp. 275, etc.; E. T. Newton, "Catalogue Cretaceous Fossils," 'Geol. Survey,' 1878.

‡ De Rance, 'Geol. Mag.,' 1874, p. 247; Downes, 'Quart. Journ. Geol. Soc.,' Vol. xli, p. 23.

Mr. Clement Reid in 1874 as about five inches thick, containing small pebbles of quartz, jasper, grit, and eruptive rocks, with fish-teeth and derived Lias fossils.* The Gault is from 20 to 25 feet thick, and consists of dark-blue micaceous loam, which merges upwards into the Upper Greensand. Clear sections are rarely to be seen. Among the fossils are *Ammonites splendens*, *Aporrhais orbigniana*, *Natica gaultina*, *Cucullæa carinata*, *Inoceramus concentricus*, *Lima parallela*, *Nucula ovata*, *Panopæa plicata*, *Pecten orbicularis*, etc. As remarked by Mr. Downes, the Gault itself is pervious to such an extent that the springs are thrown out by the Lias clay beneath.

Mr. De Rance noted the occurrence of Gault also at Golden Cap, Stonebarrow, and Pinney Cliff. It appears to thin out east of Sidmouth. The evidence of the fossils tends to show that the Gault of Black Ven is Lower Gault (zone of *Ammonites lautus*), and that it underlies the "Blackdown beds," which represent the zone of *A. inflatus*.

In other parts of England the Upper Greensand and Gault are intimately connected, gradually replacing one another, so that while in the far west we have only sandy beds that are best termed Upper Greensand, in the east, as at Burham, in Kent, we have only clayey beds that are best termed Gault.

Above the Gault at Black Ven there is from 70 to 80 feet of yellow, grey, and (in places) glauconitic sand, covered by 20 feet or more of broken chert-beds and surface-detritus. The lower portion of these sands contains bands of the indurated sandstone-concretions called "Cow-stones." The origin of the name is not very clear, but Conybeare has suggested that the tumbled blocks that lie scattered on the slopes below the cliffs may have been taken to resemble cattle, much in the same way, I presume, as the Sarsen-stones have been likened to grey wethers.

The Greensand is, on the whole, rather destitute of fossils, but about 50 feet above the Gault Mr. Downes obtained a nest of shells, fragmentary and silicified, like poor Blackdown specimens. Among these were *Turritella granulata*, *Cardium proboscideum*, *Cucullæu glabra*, *Cyprina cuneata*, *Pecten quinquecostatus*, etc. Teeth of *Lamna appendiculata* have also been recorded from the neighbourhood. The upper portion of the sands, termed the Fox

* See also R. Etheridge, *Ibid.*, p. 26, and Vol. xxxviii, p. 93; and Meyer, Vol xxx, p. 370.

mould by De la Beche, is exposed in the road between Charmouth and Lyme Regis. The cutting is known as the "Devil's Bellows," because the full fury of the wind is felt there during a storm. Returning by this road (a deviation from the old coach-road), which was made in 1825, attention was drawn to the great slip by which a portion of the road soon afterwards subsided about 20 feet.

On the return to Lyme Regis a more prolonged visit was made by some of the Members to the store-house of Mrs. Dollin.

April 20th.—On Saturday the Members started by coach and break for Chidcock. Passing through Charmouth, attention was called to the occurrence of Pleistocene Mammalia in the river-gravel of Lyme Regis and Charmouth. Mammoth and Rhinoceros have been recorded.* While in the Axe Valley, at Broom, in the parish of Hawkchurch, above Axminster, palæolithic implements, fashioned out of Greensand chert, were discovered in 1878 by Mr. W. S. M. D'Urban.†

Traces of a "Submerged Forest" have been noted at the mouth of the Char, where the sea has encroached on to the Alluvium.‡

From Charmouth there was a fine view inland across the Vale of Marshwood, a tract of somewhat cold and stiff Lias Clay bordered by more fertile, lighter lands of Middle Lias and Midford Sands. The vale includes some excellent pasture-land, and yields a good soil for orchards; hence the Dorset butter and cider are noted.§

The outliers of the Greensand, of which Golden Cap and the Pillesdon and Lewesdon Pens (909 and 934 feet high) are conspicuous examples, are for the most part uncultivated tracts clothed with gorse or fir-woods, thus contrasting with the fertile knolls nearer Bridport and Beaminster, formed of Midford Sands.

On reaching Chidcock some of the Members paid a brief visit to the Church, and the party then walked to the sea-shore at Seatown. Turning their steps eastwards, they proceeded along the base of the cliffs to Down Cliffs, under Thorncombe Beacon. Here is to be seen the finest exposure of the Middle and Upper Lias beds, although the latter are not easy of access.

* De la Beche, 'Report,' p. 412; Buckland, 'Reliquiæ Diluvianæ,' p. 174; and 'Trans. Geol. Soc.,' Ser. 2, Vol. i, pp. 94, etc.

† 'Geol. Mag.,' 1878, p. 37. See also J. Evans, 'Journ. Anthrop. Inst.,' Vol. vii, p. 499.

‡ De la Beche, 'Report,' p. 417; and 'Phil. Mag.,' Ser. 2, Vol. vi.

§ L. H. Ruegg, 'Journ. Bath and W. Eng. Soc.,' Vol. viii, p. 180.

A general view of the cliffs, which at Thorncombe Beacon rise to a height of 509 feet, showed the following succession:—

		Feet.	In.
Chart Gravel, Upper Greensand, etc. ... ... about		57	0
Midford sands		140	0
Upper Lias clay		70	0
Junction bed		1	6
Middle Lias.	Yellow sands	60	0
	Bluish sandy clay	10	0
	Laminated beds, grey and brown sands with layers of flaggy Sandstone; Margaritatus-bed on top	80	0
	Starfish-bed	4	6
	Clays with *A. margaritatus* [full thickness 160 feet]	86	0
	[Three Tiers, seen in Golden Cap, forming a division 35 feet thick.]		
		509	0

The Midford Sands, locally known as the Bridport and Yeovil Sands, comprise the zones of *Ammonites opalinus* and *A. jurensis*. From these beds *A. insignis*, *A. variabilis*, *Rhynchonella cynocephala*, etc., have been recorded. They correspond approximately with the "Cephalopoda-bed" and Cotteswold Sands, for, disregarding minor palæontological divisions, we may take these to represent also the zones of *A. opalinus* and *A. jurensis*.*

The Upper Lias clay which merges up into the sandy beds above has not been much worked for fossils, but it may be more readily examined in some places inland, to the north of Bridport. Its basement bed, as observed by Mr. Day, is a hard and compact, pale yellow and pink-coloured limestone, yielding *Ammonites bifrons*, *A. serpentinus*, and *A. communis*; and this is united with a thin bed of brown and grey ironshot and nodular limestone or Marlstone below (the "*Pleurotomaria*-bed" of Mr. Day), which yields many Gasteropods, together with *Rhynchonella acuta*, *R. tetrahedra*, *Terebratula punctata*, *Belemnites*, *A. communis*, etc. Mr. Beeby Thompson looks upon it as the equivalent of the "Transition bed" of Northamptonshire, which also contains an

* I do not agree with Mr. S. S. Buckman in placing portions of the Cotteswold Sands in the zone of *Ammonites communis*. 'Quart. Journ. Geol. Soc.,' Vol. xlv, p. 469.

admixture of Middle and Upper Lias fossils. The beds below, consisting of yellow micaceous sands and indurated bands, much resemble the Midford Sands above, and were, indeed, grouped with the Inferior Oolite in De la Beche's first section.*

Most of the fossils obtained from the Middle and Upper Lias of this portion of the coast have been procured from the fallen blocks that lie on the beach; but these blocks are of marked lithological character, and can be traced after a little investigation to their parent sources. Thus we find, in addition to the Junction-bed of Upper and Middle Lias, blocks of brown sandy limestone yielding *Belemnites*, *Gryphæa cymbium*, *Pecten æquivalvis*, and *A. margaritatus*, belonging to the "*Margaritatus*-bed" of Mr. Day, a band that occurs on top of the laminated beds noted in the general section (p. xl).

The most conspicuous blocks are those belonging to the Starfish-bed, which has yielded *Ophioderma Egertoni* and *O. tenuibrachiata*. The carefully chiselled-out hollows on the smooth under-surfaces of this hard micaceous sandstone indicate the former presence of these organisms, which have been objects of search by fossil-collectors for many years. It is difficult now to procure an example *in situ*.

Small specimens of *Ammonites margaritatus*, together with *Leda graphica*, etc., occur in the blue clays at the base of the cliffs between Seatown and Down Cliff. No Saurians and few Fishes have been recorded from the Middle Lias of this region.

Returning along the shingle to Seatown, a short halt was made for lunch, and the Members then directed their steps westwards towards Golden Cap. The blue clays at the base of the cliff in this direction were seen to belong to a different zone, for a considerable fault occurs in the valley; and instead of *Ammonites margaritatus* found east of Seatown, the predominant form was *Ammonites latæcosta* of Sowerby. Portions of this Ammonite are abundant, while more perfect specimens are comparatively rare. Examples are obtained from the nodules of limestone, the chambers being usually filled with calc-spar tinged with a green colour. The specimens when cut and polished are known as "Green Ammonites," and Mr. Day adopted the name "Green Ammonite beds" of the local collectors for this division of the

* 'Trans. Geol. Soc.,' Ser. 2, Vol. i, Pl. VIII. A reduced copy of this section accompanies Mr. G. Casley's 'Geology of Lyme Regis.'

Lias. Associated with this Ammonite we find *A. loscombi*, *A. fimbriatus*, and *A. davoei*, as well as the "Henleyi Ammonites," *A. striatus*, *A. henleyi*, and *A. bechei*. *A. latæcosta*, as remarked by Oppel, is a Capricorn Ammonite, and the beds may be said to represent the zones of *A. capricornus* and *A. henleyi*. Wright, indeed, regarded *A. latæcosta* as the middle age form of *A. henleyi*.

At the base of the Green Ammonite Beds we find a layer of pale grey earthy limestone, yielding *Ammonites henleyi*, *A. fimbriatus*, etc.

This is the Belemnite Stone of Mr. Day, so called because it yields a profusion of Belemnites. These fossils also prevail in the dark shales immediately beneath, and where these beds are exposed on the foreshore at low tide, a little to the south-west of Golden Cap, there is a grand exhibition of Belemnites and other fossils, including *B. longissimus*, *B. elongatus*, *B. clavatus*, *B. penicillatus*, etc., together with *Waldheimia numismalis*, *Plicatula spinosa*, and other forms. These Belemnite Beds no doubt represent the zones of *Ammonites jamesoni* and *A. ibex*.*

Golden Cap, 619 feet high, is no doubt the grandest of the Lias cliffs in Dorsetshire.† Its outlines are very varied, the precipices and slopes being scarred by deep channels and chines separated by irregular peaks of Lias clay; while the thick bands of calcareous sandstone, known as the "Three Tiers," which rest on the Green Ammonite Beds and constitute the base of the Middle Lias, form great buttresses in places. The Lower Lias clays at the base of the cliff are much contorted in places from the effects of great slips.

A long walk over the shingle brought the party to St. Gabriel's Mouth, on the west of Golden Cap, and thence many of the Members made the ascent of the hill and enjoyed the fine prospect it afforded. The hill is capped by a considerable thickness of chert and flint gravel and sands belonging to the Upper Greensand, and on a sunny day these beds appear in marked contrast with the dark Liassic clays beneath; hence the appropriate name of Golden Cap.

Assembling again at Morecombelake, the Members met their conveyances, and were driven back to Lyme Regis.

* Dr. Wright confessed his inability to define the limits of these zones, Lias Ammonites. 'Palæontograph. Soc.,' p. 68.

† See Horizontal Section, Geol. Survey, Sheet 21, by H. W. Bristow.

April 21st.—On this morning the party divided, some Members driving to Rousdon, while others preferred to walk thither by the footpath along the undercliffs. Those who walked had a pleasant, though often very rough, path to traverse. They were, however, rewarded by the romantic scenery, and near Charton Bay, below Rousdon, they had the opportunity of seeing the lower portions of the Rhætic Beds, the Grey Marls (35 feet thick), which are exposed resting on the Red Marls; while higher up occur the Black Shales (20 to 30 feet thick), much obscured; and above, the White Lias was to be seen. A thin representative of the Cotham Marble here occurs. The Black Shales, with *Avicula contorta*, and the Bone-bed, with *Hybodus*, *Gyrolepis*, *Saurichthys*, etc., are best seen still further west at Culverhole, east of Axmouth.*

The Members became united again at the Great Landslip of Bindon and Dowlands. An opportunity of visiting this was kindly afforded by Sir Henry Peek, through his son, Mr. Cuthbert E. Peek; and under the guidance of Mr. C. Grover the leading features were examined.

The entire coast-line from Lyme Regis to Axmouth is formed of a remarkable series of cliffs and undercliffs. From one point of view it tells of ruin and devastation, but the results, clothed as they are by Nature, form most picturesque objects. The main cliff is formed of Chalk, with here and there detached pinnacles, as the Chimney Rock under Ware Cliffs, while at a lower level we find the brown crags of the Upper Greensand. The slopes beneath, based on Lias Clay, Rhætic beds, and Keuper Marl, are strewn with the *débris* of Chalk and Greensand. Landslips, great and small, have occurred at various places from time immemorial, and the series of cliffs, from which masses have broken away, is named for the most part from adjoining homesteads; thus we have the Ware, Pinhay, Charton, Whitlands, Rousdon (or Rowsedown), Dowlands, Bindon, and Haven Cliffs. One important founder is stated to have occurred in 1765, when the undercliff at Whitlands was formed; but the most celebrated one, and, perhaps, the most extensive slip that has occurred during the present century in this country, is that which took place near Bindon and Dowlands in 1839. The summer and autumn months had been extremely wet, and for more than a week previous to the founder cracks had been

* Egerton, 'Proc. Geol. Soc.,' Vol. iii, p. 409.

observed along the brow of the cliffs. The slipping began early on Christmas morning, but the main mass subsided on the following day, when about 20 acres of land broke away, and foundered towards the shore. The result was a chasm from 200 to 400 feet broad, from 130 to 210 feet deep, and about half-a-mile long, in the midst of which smaller broken masses subsided to a lower level than the main landslip. The pressure of the foundering strata upheaved the sea-bottom adjoining the coast, producing a reef (nearly three-quarters of a mile long and 40 feet high in places), which was at the time covered with marine organisms.

Coastguards spoke of flashing lights and of an intolerable stench, phenomena attributed by Conybeare to the violent attrition of the beds of flint and chert that subsided. The consternation in the neighbourhood was great, many persons attributing the occurrence to an earthquake. Indeed 'A brief account of the Earthquake' was published in London, the writer endeavouring to show that it was prophesied in the 'Revelations.' The inference that an earthquake was the cause is interesting, for there is a record of an earthquake having happened at Lyme in 1689; a fact that warns us not to place too great reliance on such records.

The cause of this and other landslips along the coast is due partly to the gentle seaward dip of the Cretaceous strata. At Bindon the Chalk dips 5° S., 20° E. Moreover, we have these porous rocks based on a slippery foundation of Lias and other clays. The Lias probably does not extend west of Dowlands, but then we come upon the Rhætic Clays and the Keuper Marls, equally slippery as a foundation.

The lower beds of the Greensand become saturated with water, and springs are thrown out at various intervals. The sand, as Conybeare remarks, would be in a semi-fluid condition, and much of it would be carried away in wet seasons by the springs.* In some cases also the streams erode deep channels in the clays, which channels would be partially filled up with strata from above. Thus the superincumbent rocky beds are undermined, their founda-

* At Rousdon the Members had the opportunity of seeing the fine pictorial work of Conybeare and others. Its title is 'Ten plates . . . representing the changes produced on the coast of East Devon . . . on the 26th December, 1839, and 3rd of February, 1840. From drawings by W. Dawson, the Rev. W. D. Conybeare, and Mrs. Buckland. With Geological Memoir and Sections by the Rev. W. D. Conybeare. The whole revised by Prof. Buckland.' Oblong, London, 1840. See also G. Roberts, 'An Account of and Guide to the Mighty Landslip of Dowlands and Bindon,' Ed. 5, 1840.

tion gives way, cracks are formed along the cliffs, and ultimately large masses fall away or subside.

Although most persons are impressed with the grandeur and beauty of the scene, yet Murray, in his Guide (1859, p. 152), says, "The great chasm will probably disappoint. It too much resembles a gravel-pit!"

In the course of the day sections of Greensand and Chalk were to be seen. The beds are exposed by the road leading from Rousdon to the beach, but better opportunities of examining the beds were obtained in the landslip.

The general section of the Greensand may be given as follows:—

		Feet.
Zone of *Pecten asper.*	Hard Calcareous Sandstone and Sands, with *Pecten quinquecostatus*	5 to 25
	Chert-beds, with *Pecten quadricostatus* ...	20 to 35
Zone of *Exogyra conica.*	Yellow Sands (Fox Mould)	40 to 60
	Grey and Greensands, with indurated nodules (Cow stones) yielding Crustacea, etc. ...	25 to 40

The total thickness of the beds may be estimated at 180 feet, but the character and thickness of each sub-division varies in different places.*

In connection with the chert-beds attention was drawn to Dr. Hinde's researches on the sponge-spicules, which form much of the rock. They are composed of chalcedony, and their canals are infilled with glauconite, while they are imbedded in a matrix of chalcedonic, and sometimes of amorphous, silica.

A good account of the Chalk and Greensand was communicated to the Geological Society in 1825 by De la Beche.† The Chalk includes beds with flints and hard nodules, and at the base a layer with quartz grains, and sometimes a fossiliferous band known as the Chloritic Marl. The thickness in the district is from 150 to 200 feet.

Few fossils have been recorded from the Chalk between Lyme Regis and Axmouth. These include *Ptychodus decurrens*, *Inoceramus*, *Terebratula semiglobosa*, *Terebratulina gracilis*, *T. striata*.‡

At Beer Head (west of Axmouth), of which the Members obtained a distant view, the beds have been worked out in much

* The thickness assigned by De la Beche is excessive. Probably he included the overlying chert detritus, etc. 'Trans. Geol. Soc.,' Ser. 2, Vol. ii, pp. 109, etc. See also C. E. De Rance, 'Geol. Mag.,' 1874, p. 253.

† 'Phil. Trans.,' 1885, p. 418.

‡ E. T. Newton, "Cat. Cretaceous Fossils" ('Geol. Survey').

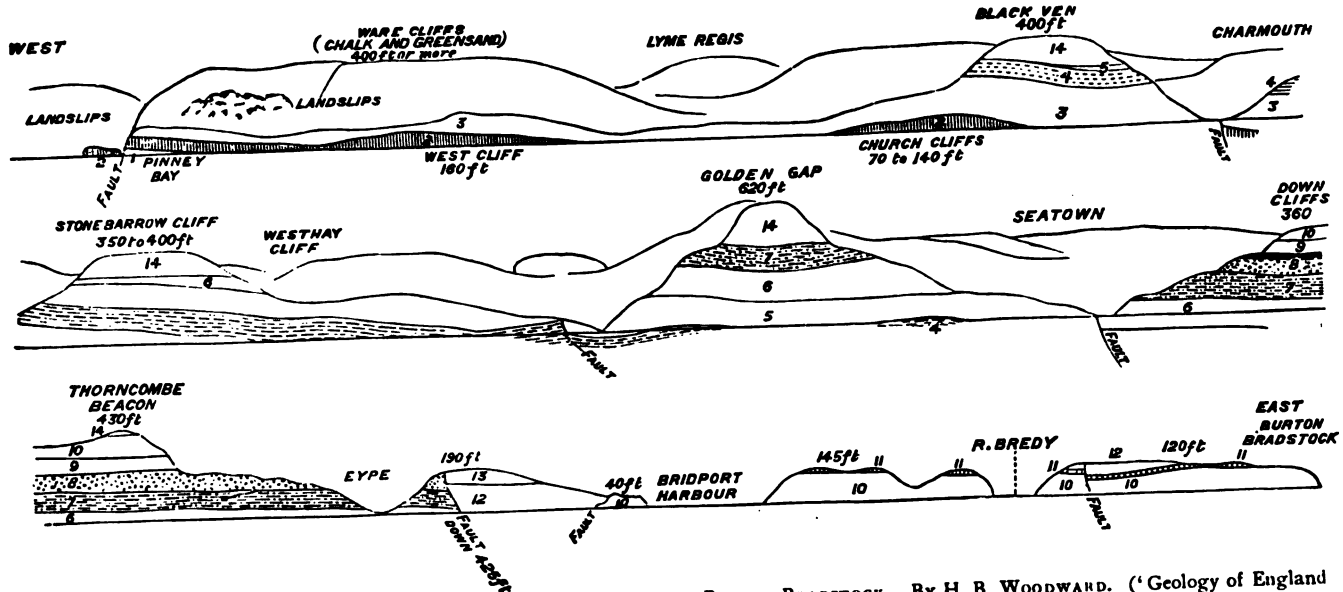


FIG. 1.—SECTIONS OF THE DORSETSHIRE CLIFFS, FROM LYME REGIS TO BURTON BRADSTOCK. BY H. B. WOODWARD. ('Geology of England and Wales,' Edit. 2, p. 252.) Horizontal Scale one and a half inches to a mile. Vertical scale much exaggerated.

14. Chert gravel. Upper Greensand and Gault.
13. Forest Marble.
12. Fuller's Earth.
11. Inferior Oolite.
10. Midford Sands.
9. Upper Lias.
8. Sand.
7. Laminated Beds.
6. Starfish Bed. Clay with *Ammonites margaritatus*. Three Tiers (stone-beds). — Middle Lias.
5. Clay (Green Ammonite Beds).
4. Pale-grey Marl (Belemnite Beds).
3. Dark clays and shales.
2. Limestones (Blue Lias).
1. White Lias. Rhætic Beds. — Lower Lias.

detail by Mr. C. J. A. Meyer.* The uppermost layers yield *Micraster cor-anguinum*, etc. The Beer Stone, much lower down, yields *Inoceramus mytiloides*. Fitton thought it might represent the Totternhoe Stone, and it is interesting to learn on the authority of G. Roberts that a similar bed of hard sandy chalk was formerly dug at Ware, near Lyme Regis. Green grains, quartz grains, and sometimes phosphatic nodules occur in the lower beds of Chalk. The bottom bed yields *Ammonites rothomagensis*, *Scaphites æqualis*, *Holaster subglobosus*, etc. This is the same as the Chloritic Marl of Chard, but while found in other places it has not been observed in its fossiliferous character near Lyme Regis, where the Chalk with quartz grains, three to six feet thick, rests directly on the Greensand, and where, as Mr. Whitaker has remarked, "it is often hard to mark the junction."†

It is noteworthy that many of the fossils taken to indicate special horizons in the Chalk in other parts of England have a varying range in the west.

The occurrence of *Holaster subglobosus*, *Ammonites rothomagensis*, and *Terebratula semiglobosa* in the basement-beds of the Chalk in the West of England is significant; and we may fairly speculate on the likelihood of chalky conditions having come on earlier in the east than in the west. Indeed, if we take the case of the Red Chalk at Hunstanton, there is no doubt about the matter.

In connection with this subject it is noteworthy that we have a fairly conformable sequence from Purbeck beds to Chalk in the South-east of England. The same conformable succession from Portlandian beds to Chalk in East Yorkshire has lately been maintained by Mr. G. W. Lamplugh. As we proceed westwards, both in the South of England and in Lincolnshire and Yorkshire, there is an overstep of certain members of the Cretaceous system—an overstep marked by upheaval and denudation of the Jurassic rocks in the west. In the South of England this upheaval appears not to have taken place until after the deposition of the Wealden strata, for these beds partake of the general dip that affects the underlying Jurassic strata. Then we have the overstep of the Lower Greensand, as shown in Wiltshire, etc., and, finally, the overstep of Upper Cretaceous strata, which extend beyond the

* 'Quart. Journ. Geol. Soc.,' Vol. xxx, p. 393. A. J. Jukes-Browne 'Geol. Mag.,' 1877, p. 361. Barrois, 'Recherches sur le Terrain Crétacé Superieur de l'Angleterre,' 1876, p. 75.

† 'Quart. Journ. Geol. Soc.,' Vol. xxvii, p. 97. See also Fitton, *op. cit.*, 'Trans. Geol. Soc.,' Ser. 2, Vol. iv, p. 234.

Lower Greensand somewhere to the east of Upway, in Dorset, and again east of Dinton, in the Vale of Wardour.

Attention was drawn to the superficial accumulations that occur on the Cretaceous tracts. The higher grounds of Chalk, and also Greensand, are covered with an irregular bed of Flint and Chert detritus, reminding one of the Clay-with-flints of Buckinghamshire and Hertfordshire, when that accumulation contains very little clay. Near Lyme Regis and Axminster the bed is mainly formed of broken portions of flint and chert in a clayey or loamy matrix, sometimes nearly 50 feet thick. The bulk of the material is, therefore, local, and sometimes but slightly re-assorted. It is noteworthy, however, that rolled fragments of grit and quartzite and pebbles of quartz, some of large size, are met with. These foreign pebbles were observed by Buckland in 1823, who then observed that they must have been drifted thither before the present valleys were excavated.*

Evidently the bed itself has been to some extent modified during the vicissitudes of the Glacial epoch.† The foreign water-worn materials, in Mr. Ussher's opinion, may have resulted from a redistribution of Tertiary gravels, and he has suggested that the accumulations of chert and flint, if not due directly to ice-action, may date back to the period when the great accumulations of "Head" were formed in many places along our western coasts.‡

Doubtless of the same age are the gravel-beds by the Hardy Monument, above Portisham, on the east, and near Newton Abbot on the west.

Returning to Rousdon, the seat of Sir Henry Peek, the Members were conducted over the observatory, which is a Second Order Station of the Royal Meteorological Society. Here observations are regularly made by Mr. Grover, under the superintendence of Mr. Cuthbert E. Peek, and an annual report is published. The various instruments were explained by Mr. Grover, and much interest was taken in the evaporation experiments, and also in an arrangement for recording oscillations of the earth's surface. This latter consisted of a solid mass of Beer Stone, 15 feet in length and two feet square, imbedded 10 feet in the earth, on the top of which spirit-levels were placed. These indicated from time to time trifling inclinations east and west.

* 'Reliquiæ Diluvianæ,' p. 247.
† H. B. W., 'Geol. Mag.,' 1874, p. 335.
‡ 'Quart. Journ. Geol. Soc.,' Vol. xxxiv, pp. 449-458. See also De Rance, 'Geol. Mag.,' 1874, p. 247.

A hearty vote of thanks was accorded to Mr. Grover, and also to Sir H. Peek and Mr. C. E. Peek for their courtesy in permitting the Members to examine the Landslip on a day when the public are usually excluded.

April 22nd.—On Easter Monday the Members took leave of Lyme Regis, and, after being driven to Bridport, took train to Upway Station, where they were met by Mr. Hudleston, who now took the direction of the party.

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EASTER EXCURSION, 1889.

EXCURSION TO WEYMOUTH.

Easter Monday and Tuesday, April 22nd and 23rd.

Director: W. H. Hudleston, F.R.S., Sec.G.S.

(*Report by* The Director.)

April 22nd, Easter Monday.—The principal portion of the party, viz., that from Lyme Regis, reached Upway Station about 11.30 a.m. Contingents from London and Bath joined subsequently. A move was made in the direction of Elwell, at the foot of the Ridgway Rise. The Director had to announce that the clay-pit in the railway-cutting at the foot of the hill had been closed since the last visit of the Association ten years ago. Moreover, there had been very little fresh working in the stone-quarries on the hill lately. The lower division of Portland Stone, known as the chalky or flinty series, has been here quarried for lime, but there is no section showing the actual base. A

line of fossils with large ammonites (*? A. boloniensis*) is conspicuous towards the base of the quarry, and it was somewhere in this portion of the series that a Member of the Association obtained the specimen of *Ischyodus townsendii*, described by Mr. E. T. Newton in 'Proc. Geol. Assoc.,' Vol. vii, p. 116. The upper division of the Portland Stone, which contains the building-stone series, is but poorly developed in this quarry. There is also another point of difference, viz., that the Lower Dirt-bed of Portland Isle seems to have no representative here, since the Portland and Purbeck Limestones are welded into one block, just as is the case at Chicksgrove in the Vale of Wardour. This is, however, no proof of conformity. As time was short, the party did not visit the Purbeck portions of these quarries.

The prospect from this slope is extensive, and the weather being unusually clear, the interesting physical features in connection with the Weymouth anticlinal were very distinct. The Director pointed out some of the localities where the sharp dips on the north side of the axis and the gentle slopes on the south side seem almost to tell their own story. In this remarkable triangle, which has the Chalk escarpment for its base and the Bill of Portland for its apex, the whole of the Middle and Upper Oolites (or Upper Jurassic) are exhibited in duplicate, and he observed that it would be one of the objects of the present Excursion to compare the different developments of the several series on either side of the anticlinal. As a rule, it would be noted that the deposits were thicker on the south. This is especially noticeable in the Corallian and Portlandian rocks. Further remarks on the age of the anticlinal and its correlation with similar phenomena in other districts the Director would postpone till later in the day.

The party now moved a little higher up the Ridgway Hill, so as to command a thoroughly good view of the cutting, which has formed the subject of some interesting papers by Mr. C. H. Weston in the 'Quarterly Journal of the Geological Society (Vol. iv, pp. 245-256; Vol. v, pp. 317-319; and Vol. viii, pp. 110-120). Previous to the making of this cutting no one suspected such a large development of the Wealden or Hastings series so far west. Since the beds dip at a very high angle towards the fault the thickness must be very considerable. There is no trace now of the curious dyke-like development of

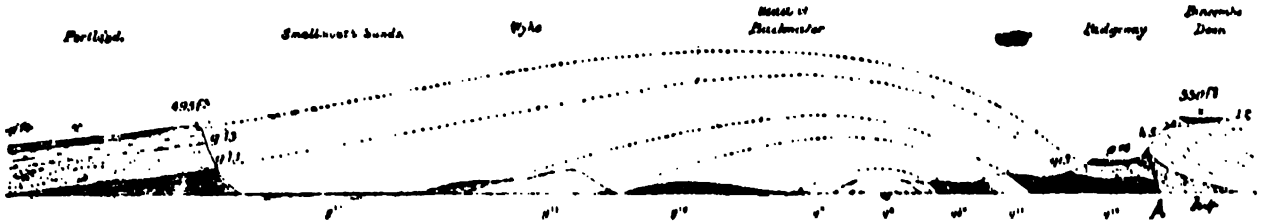


Fig. 1. - The Weymouth Anticlinal.—g^8 and g^9, Forest Marble and Cornbrash. g^{10}, Oxford Clay. g^{11}, Corallian. g^{12}, Kimeridge Clay. g^{13}, Portland Sand. g^{14}, Purbecks. A^4, "Upper Greensand." A^5, Chalk. i^2, Lower Tertiaries. x, Quaternary Deposits. A, Ridgway Fault. (Reduced from Prof. Prestwich's section 'Q. J. G. S.,' Vol. xxxi.)

Oxford Clay depicted and described by Mr. Weston, which abuts against the actual fault, unless it be in the shape of a long stone drain, which would seem to indicate argillaceous material. One of the party remembered that *Gryphæa dilatata* had been picked up at the spot ten years ago.

To account for the presence of this Oxford Clay in such a peculiar position has somewhat exercised geologists. The most probable supposition is that there exists a double fault here, and that one of the faults is of pre-Cretaceous age, pointing to extensive pre-Cretaceous denudation. Thus the base of the Upper Cretaceous (here the Upper Greensand) at Ridgway may really rest upon Oxford Clay, as is represented to be the case at the inlier of East Compton, a few miles to the north-west. In this case the Wealden-Purbecks would not pass under the Chalk, as they are bound to do, if this were a simple fault heading to the downthrow in the ordinary manner. Thus the old line of disturbance seems to have become a line of weakness in post-Cretaceous times, although the direction of the throw must have been reversed.

Seen from a distance, the enormous deposits of bleached flint gravel on the top of Bincombe Downs have very much the appearance of the Chalk on which they rest. Hereabouts, also, the boring-rod disclosed some sixty feet of Lower Tertiaries, doubtless an extension of the much larger patch on Blackdown, which constitutes the most conspicuous summit of the great escarpment. The route of the party, however, was quite in an opposite direction. After effecting a junction with the contingents which had lately arrived at Upway Station, the entire party proceeded in carriages to the neighbourhood of Osmington Mill, a pleasant drive of about five miles. The route for part of the distance lies in the Kimeridge Clay hollow, and there are good views of the Portlandian and Chalk escarpments on the left. Above the village of Sutton Pointz the great figure cut in the chalk slope representing George III. on horseback had evidently been lately cleaned out, and became a very conspicuous object.

On arriving at Osmington Mill the party made at once for the seashore. The path at the edge of the cliff very nearly coincides with the position of the great fault, which, after running parallel to the coast, passes through Lodmoors, and

ultimately merges in the axis of the Weymouth anticlinal. This is probably the most important disturbance in this part of the South of England, becoming much more intense as we pass eastwards both in the Isle of Purbeck and at the back of the Isle of Wight. Its effects may be traced in the well-known section at the termination of Ballard Down, which is so graphically depicted in Sir Henry Englefield's work.

Before the party started on their arduous walk the Director took the opportunity of making a few remarks as to the age and relations of this great fault. Few persons now believe that the Weymouth anticlinal is of so recent a date as was supposed at one time by Prof. Prestwich. If there are difficulties with respect to the age and mode of formation of the gravels on the Isle of Portland, surely such difficulties are small compared with the acceptance of a hypothesis which requires such an immense amount of meteoric denudation and sculpture within so comparatively recent a period. He failed to see why these movements should be separated in time from the general system known as the "Folding of the Downs." This probably occurred during the Oligocene period, when the principal flexures and fractures in the South of England having an approximately east and west direction came into existence. Since that period an enormous quantity of land in the direction of the Channel has been planed away by marine denudation, and of this land the Island of Portland, preserved by a series of physical accidents not yet explained, is a remnant.

The Weymouth anticlinal possesses an important physical feature in common with the three great anticlinals of the South of England, viz., that the north wing is the steepest and consequently the shortest—a feature particularly marked in the Vale of Wardour. Thus has come about the idea that in all these movements, which originate in the shrinkage of the earth's crust, the beds have been thrust from the south towards the north.*

The general effects of the dislocation along the shore are somewhat masked by the sliding forwards of the Kimeridge Clay from the higher parts of the cliff; but the confused and tilted position of the Corallian beds bear testimony to its

* For further remarks on this subject generally, see 'Proc. Geol. Assoc.,' Vol. vii, p. 178, *et seq.*

force. The Corallian section was estimated by Blake and Hudleston* to be about 180 feet thick on this coast. The equivalents of the Nothe Grits and Clays, and of the Bencliff Grit, may be taken as constituting the Lower Calcareous Grit of this section, and they are visible at the Cascade, where the large "cheese" doggers, which originate about the base of the Bencliff Calc Grit, sliding over the Nothe Clay, are scattered all over the scaur at this point like so many stranded whales. The Osmington Oolites, which succeed, constitute an important and fossiliferous member of the Corallian series, and above these come the Main Limestones, capped by the *Trigonia*-beds. It was along the highly-inclined outcrops of these beds that the party had to scramble on their way to Jordan Hill, but as the afternoon was fine, the task, though slow, was not very arduous. About 2½ miles, straight, were accomplished in three hours, and the carriages having been regained at the Coastguard Station, the party proceeded to Weymouth.

April 23rd, Easter Tuesday.—The party, after crossing the ferry, made for the summit of the Nothe ridge, where the Director briefly indicated the plan for the day. It was proposed to spend a couple of hours in examining the Corallian series from the Nothe to Sandsfoot. Here the beds, dipping towards the south at a moderate angle, and quite free from dislocation, afford an excellent opportunity for studying the sequence. The series is estimated (*op. cit.*) at 230 feet; the two Lower Grits and intervening clay being more than twice as thick as the corresponding part of the series at Osmington, whilst the equivalents of the Osmington Oolites suffer a corresponding diminution. The *Trigonia*-bed series, or Main Corallian Limestone, affords a rough, though nearly level, platform for several hundred yards (dip 8·5°) in the little bay between Bencliff Point and Sandsfoot Castle. Above this platform succeed what may be termed the Upper Corallian beds, commencing with the Sandsfoot Clay and continued by the Sandsfoot Grits, with occasional clays. There was no time to take more than a passing look at these, but the Director pointed out the sudden and immediate change from the Corallian Limestones (represented in other districts by Coral Rag and Coralline Oolite) to clays which were in some

* 'Q. J. G. S.,' Vol. xxxiii.

respects Kimeridgian in character, these being succeeded by red grits full of large Monomyaria and with a tendency to ferrugination in their upper parts. The Abbotsbury Ironstone is probably on the horizon of the clays and sandy beds of the upper part of the Sandsfoot Grits, and may be regarded as on the borders of the Corallian and Kimeridge.

The party now doubled back towards Weymouth, and after inspecting the Rodwell cutting took train for Portland. Here they were joined by Mr. Wallis, who acted very efficiently as local guide. The slope of the escarpment on the west side of the Vern Fort was ascended to a point where a new incline had been constructed, leading to the Admiralty quarries on the plateau. No better section of Portland Stone, or one more easily examined, has ever been made. The cutting of the incline commences at the top of the indurated Portland Sand, and displays several feet of Portland Clay, though this deposit is said to be variable in thickness.* As is well known, the Portland Stone of the island is divisible into two portions—the Lower or Cherty series and the Upper or Building-Stone series. The lower series is a sort of impure Chalk full of brown and black chert, which possesses no economic value, beyond that of filling up a hole where necessary, but there are several lines of fossils. Each of these can be examined inch by inch, and thus a fine opportunity must have been afforded to obtain the numerous varieties of *Trigonia gibbosa*, for beautiful specimens of which this rock is so remarkable. The Building-Stone series here consists of two thick beds of freestone (*Base bed* and *Whit bed*), separated by a coarse fossiliferous and flinty series, part of which is termed the Curf. The "Roach," which terminates the Portland Stone upwards, contains a fine and varied series of fossils, which on the whole are of a very different character to those of the Cherty series. Numerous minute Gastropoda, often associated with small Conchifera and triradiate sponge-spicules, the shells chalcedonized, characterize the topmost layer of the Roach.

* This clay is represented in the section appended to Mr. W. Gray's paper "On the Geology of the Isle of Portland," 'Proc. Geol. Assoc.' (Vol. i, p. 132), and is duly recorded by Prof. Blake in the "Portland Rocks of England" ('Q. J. G. S.,' Vol. xxxvi), but appears to have escaped the notice of the author of the section given by Mr. Damon ('Geology of Weymouth,' etc., 1884, p. 81).

The party were next conducted through the Vern ditch to the east side of the island, where an interesting view can be obtained looking down upon the Breakwater, and an advance was made for a short time in the direction of the convict prison. Ultimately, having now gained the summit of the plateau, the party proceeded to inspect some of the private building-stone quarries, where the various phenomena in connection with the Roach, the Lower Dirt-bed, the Skull Cap, and the Main Dirt-bed with its "Burr" Trees were observed and duly discussed. Although there is not much left of the Lower Purbecks on Portland Island, doubtless that little is of extreme interest. A novel feature in connection with the calcareous rings which environ the "Burr" Trees was mentioned by Mr. H. B. Woodward. A tree occurring horizontally in the Dirt-bed at Portisham had a calcareous envelope of such large dimensions and singular shape that it was pronounced by the local authorities to be a fossil elephant, and people were invited from far and near to inspect it.

The topmost group of the Purbecks on Portland Isle consists of a kind of calcareous slate, often bearing the marks of much disturbance. A few years ago some excavations were discovered in these slates which attracted the attention of Mr. Wallis, who, fortunately, bethought himself of applying to the Association for assistance in interpreting the discoveries. The result was the very interesting paper "On some curious excavations in the Isle of Portland," by the present President of the Association, Mr T. V. Holmes, F.G.S. ('Proc. Geol. Assoc.,' Vol. viii, p. 404, *et seq.*). Up to 1884 from twelve to fourteen beehive-shaped holes had been discovered. The author points out the affinities between these "Portland Pits" and the ordinary Kent and Essex Denebolles. The holes appear to have been used as granaries.

As the basing is being constantly cleared away in order to reach fresh building-stone, these pits are doomed to disappear shortly after their discovery. Those figured in Mr. Holmes' paper are in one respect more fortunate than the people who made them, inasmuch as a monument has been erected to their memory in the Proceedings of the Association. But, as good luck would have it, Mr. Wallis had lately discovered another pit or Denehole on the summit of the plateau, to which the

Members were conducted. The increasing rain had been troublesome for some time, but here it succeeded in dissolving the party, and the remainder of the programme was not fully carried out.

There was a gathering towards three o'clock of most of the Members at the Victoria Hotel. near the Station. Here Mr. Wallis displayed some of his fossils, including a very fine *Ammonites giganteus*, said to have been the second biggest ever found. After dinner the President proposed a vote of thanks to the two Directors, Mr. H. B. Woodward and Mr. W. H. Hudleston. This was duly acknowledged, and the party left Portland by train at 4.15 p.m.

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ORDINARY MEETING.

FRIDAY, MAY 3RD, 1889.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—J. J. Foster; W. G. Ridewood, B.Sc.; C. J. Smith.

The following papers were then read:—'Note on a Chelonian Humerus from the Middle Eocene of Bracklesham,' by R. LYDEKKER, B.A., F.G.S., etc.

'On Rocks from The Saas-Thal and Geneva,' by Capt. MARSHALL HALL, F.G.S., F.C.S., etc.

'Geology before 1800,' by E. LITCHFIELD.

Specimens were exhibited by Captain MARSHALL HALL and by Mr. LYDEKKER in illustration of their respective papers.

EXCURSION TO BOXMOOR AND NASH MILLS.

SATURDAY, 18TH MAY, 1889.

(In conjunction with the Hertfordshire Natural History Society).

Directors:

JOHN HOPKINSON, F.L.S., F.G.S., and JOHN MORISON, M.D., F.G.S.

(*Report by* MR. HOPKINSON.)

The Tertiary beds of the London Basin are traversed along the London and North Western Railway as far as Bushey Station, where the Upper Chalk first appears from under the Woolwich and Reading Beds which are seen in the Bushey cutting, and a chalk-pit on the right of the line, just beyond the station, shows the characteristic layers of flints. After crossing the valley of the Colne, and passing through the Watford tunnel, the line runs along the valley of the Gade as far as Two Waters, where the Gade receives its tributary the Bulborne, half-a-mile from Boxmoor Station.

The Members of the two Societies assembled at this station in the afternoon, and visited first a large chalk-pit excavated in the side of the hill called Rough Down, west of and facing the

line. Near the top of the pit there is a bed of hard cream-coloured chalk, known as the Chalk Rock, which is usually considered to form the top bed of the Middle Chalk.

After a few introductory remarks had been made by Mr. Hopkinson, a paper on the Chalk Rock was read by Dr. Morison, which is here slightly condensed.

"The Chalk Rock, which lies at the top of the Middle Chalk, is a cream-coloured, rather rubbly limestone, jointed at right angles to the plane of bedding, breaking with a more or less conchoidal fracture, and weathering on exposure to the air. The upper surface is well defined, but the lower shades off gradually into the soft chalk beneath. It contains numerous grains of glauconite, and irregularly-shaped nodules slightly phosphatic and coloured green outside by glauconite; and it also has irregularly-cylindrical branching cavities filled in many cases by a ferruginous sandy clay or containing nodules of iron-pyrites. It varies in thickness from a few inches to 10 feet; but here it is only 18 inches thick. In some places there are two bands a few feet apart. It is the lower, or principal band which contains the green-coated nodules and characteristic fossils. It does not contain flints, but I once found a quartzite pebble in it. It is the Chalk Rock which, resisting denudation more than the softer chalk, protects the slope of the Chalk escarpment to the north of us, and assists in forming the outline of the Chiltern Hills. Its fauna is peculiar, being notable for the number and variety of the Gastropoda; the Cephalopoda also are tolerably abundant; and the sponges are very numerous and varied. Through the courtesy of Mr. Whitaker I am enabled to state that the Chalk Rock differs materially in its chemical composition from ordinary soft chalk, containing more than twice as much magnesium-carbonate, nearly twice as much silica, more than three times as much sulphuric acid in the form mainly of sulphate of calcium, and a relatively very large amount (0·6 to 0·7 per cent.) of phosphoric acid in the form of phosphates. Examined microscopically, the Chalk Rock is seen to contain a number of small crystals; indeed I think its hardness is mainly due to its crystals of calcium-carbonate, in fact to the conversion of the soft chalk into a crystalline limestone; sometimes, indeed, large crystals of calcite are formed. Opinions differ much as to the depth of the sea in which the Chalk generally was

laid down, but the Chalk Rock must have been deposited in a comparatively shallow sea, a considerable elevation of the sea-bottom taking place before its deposition. Its very numerous and varied fossils show this, and especially the remarkable abundance of Gastropoda, which usually inhabit a shallow sea not far from land."

After a few fossils had been found, the pit was left for the brick-fields at Bennet's End, the route taken being by Two Waters and across the fields. These brick-fields are at a considerable height on the opposite side of the valley to Rough Down. They are on an outlier of the London Clay and Reading Beds, through which a fault runs nearly north and south, the Chalk abutting against the basement-bed of the London Clay. This is not clearly seen now, the beds not being worked in proximity to the fault, but the following section by Mr. Whitaker, reproduced from his 'Geology of London' (p. 209), by permission of the Director-General of the Geological Survey, shows what was to be seen in 1861 :—

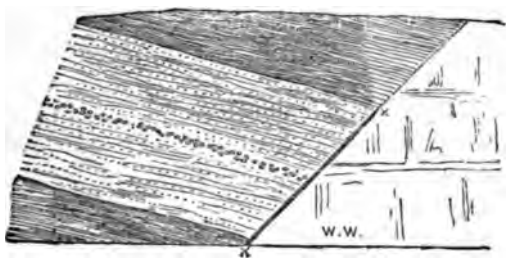


FIG. 1.—Diagram-Section of a Pit near Bennet's End.

LONDON CLAY. { *a* Roughly laminated brown clay, from 0 to about 6 feet.
Basement Bed. { *b* Brown loam, over 6 feet
c Flint pebbles and oyster shells, about 6 inches
d Brown loam, like *b*, 5½ feet } about 12 feet.

e Bluish-grey plastic clay of the Reading Beds, holding water.

f Chalk, abutting against the basement-bed of the London Clay.

xx Line of clay along the fault. (The right-hand part of the section, lightly engraved, not actually seen.)

The basement-bed of the London Clay has here yielded many fossils, a list of which is given on pages 264 and 265 of Mr.

Whitaker's Memoir. In the higher and more northerly part of these brick-fields a bed of brick-earth is now largely worked.

The route was now down the hill to the south into the valley of the Gade again, and as a rather longer time had been taken over the walk than had been anticipated, the party crossed the fields direct to Nash Mills, the residence of Dr. John Evans, F.R.S., Pres. S.A., who had very kindly invited both Societies to "tea and flint-implements." While "tea" included other refreshments, most welcome after the five miles' walk on a bright sunshiny afternoon, it was found that "flint-implements" implied a collection of antiquarian treasures which, for interest, rarity, and serial completeness in many of the departments represented, is without equal, even in any public museum.

The following are the principal objects which were exhibited:—In the Library: Palæolithic or River-drift implements from England, France, Spain, India, and Africa; Greek, Roman, Saxon, and Merovingian glass; Rhodian and Damascus ware. In the Inner Library: Neolithic or surface implements, and those of modern savages from various parts of the world; bronze antiquities of various countries; Venetian and other glass, ancient pottery, etc.; arms and implements of modern savages. In the Dining-Room: Early gold ornaments; Roman, Saxon, Merovingian, and Mediæval brooches and other antiquities; posy and other rings; Mediæval seals; Hispano-Moresco pottery. In the Drawing-Room: Greek and Roman coins and medallions; Ancient British, Saxon, and English coins and medals; early plate; ancient needlework; Lambeth pottery, and various porcelain and pottery. To give some idea of the number of the objects exhibited it may be stated that there were about 500 rings, of which between 300 and 400 have inscriptions. Of local interest was a collection of nearly 200 coins struck at Verulam, which have been discovered in various parts of the kingdom. The splendid collection of Palæolithic and Neolithic flint-implements, however, attracted the largest share of attention.

Before leaving, the party assembled on the lawn, and Mr. Rudler, in the absence of the President of either Society, proposed a hearty vote of thanks to Dr. and Mrs. Evans for their kind and hospitable reception. The return journey was made from King's Langley Station, Dr. Evans sending his carriages

to convey most of the ladies there. The Members of the Hertfordshire Society numbered about 80, and of the Geologists' Association 25.

REFERENCES.

Geological Survey Map, Sheet 7.

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——— Introduction to Pryor's 'Flora of Hertfordshire,' pp. 12-17 (1887).

WHITAKER, W.—"On the Chalk Rock." 'Quart. Journ. Geol. Soc.,' Vol. xvii, pp. 166-170 (1861).

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EXCURSION TO BRENTWOOD.

SATURDAY, MAY 25TH, 1889.

(In conjunction with the Essex Field Club.)

Directors: R. S. HERRIES, F.G.S., H. W. MONCKTON, F.G.S., and H. B. WOODWARD, F.G.S.

(*Report by* THE DIRECTORS.)

Leaving Brentwood Station, the party proceeded southwards to Warley Common, and by a private road to the Barracks. In the course of this walk, as remarked by Mr. Monckton, the party had passed from the London Clay at Brentwood Station, over the passage-beds connecting that formation with the Bagshot Sands, and on to the Bagshot beds. With these Bagshot beds there had been included by the Geological Survey certain pebble-beds, to which attention was now especially directed.

The party was first conducted by Mr. Monckton to a pit west of Warley Scrubs, where gravel had been dug to a depth of eight or nine feet. On the Geological Survey Map this was coloured as "Pebble Gravel," distinct from the "Bagshot pebble-beds." The gravel consists mainly of flint-pebbles, but contains also a number of pebbles of quartz, some of large size, as well as angular flints. Mr. Monckton explained that he did not believe this gravel was part of a marine formation, though he thought that some of the Hertfordshire Pebble Gravel, which is coloured with the same tint on the map, may be marine. In his opinion, we have in this instance merely *débris* of the neigh-

bouring more massive beds of pebbles, with a certain admixture of foreign material.

Mr. Woodward expressed his agreement with the explanation given by Mr. Monckton. When engaged in 1871, together with his colleague, Mr. F. J. Bennett, in mapping the geology of the country near Brentwood, they were often much perplexed with the many deposits of gravel, for it was most difficult to correlate them or determine their respective ages. The deposits generally grouped as Pebble Gravel were those characterized by an abundance of flint and quartz pebbles, and they were to be distinguished from the so-called Middle Glacial gravels by the absence of brown quartzites and of the derived Jurassic fossils, to be met with in the Glacial drifts. The Pebble Gravel was in the main pre-Glacial, so far as Essex and Hertfordshire are concerned; but there was no evidence to suggest that it was Pliocene. With regard to this gravel at Warley, Mr. Woodward admitted it was very doubtful if it could be classed as of the age of the main mass of the Pebble Gravel (*i.e.*, "Gravel of the Higher Plain," of Prof. Hughes), for it appeared to be due simply to local denudation of the Bagshot pebble-beds. This might have taken place during Glacial times, for Boulder Clay has been met with on the high grounds at Brentwood; and then foreign materials might have been introduced.

Perhaps the most difficult question, and one, indeed, which puzzled Mr. Wood, is, What was the source of the quartz pebbles? The question cannot be definitely answered, although it is possible that the Millstone Grit, like that of Kinder Scout, may have contributed to the supply.

Attention was drawn to the fact that here, as well as in other pits visited, the pebbles for some depth occurred mostly with their longer axes pointing downwards. Mr. Woodward remarked on the explanation given by the Rev. O. Fisher ('Quart. Journ. Geol. Soc.,' Vol. xxii, p. 553), viz., that pebbles might attain such a position in sinking through a muddy deposit. In several instances the beds are distinctly contorted, so that direct Glacial action, and, perhaps, also the influences of frost and thaw, may have combined to produce the result. Mr. Holmes remarked that in some places the Oldhaven pebble-beds present the same features.

Proceeding in a westerly direction, the party examined

several pits, opened in pebbly gravel, at the northern end of Holden's Wood, and a short distance south-west of the Warley Barracks. Here the deposit consists, as before, mainly of flint-pebbles, while quartz is found but rarely in small pea-like grains. Subangular and little-rolled flints are also met with. About 10 feet of gravel was shown, resting in places on yellow sand of Bagshot character. Mr. Woodward believed that the lower beds for a foot or two (in places) were undisturbed Bagshot pebble-beds, and in them here and there a thin, impersistent seam of white clay was observable. He remarked on the section formerly exposed near Langtons, on the eastern side of Southweald Park, where beneath six feet of the more or less disturbed pebbly gravel, with quartz, etc., there was exposed about 15 feet of the Bagshot pebble-beds.* It was this section, which he had seen in 1870, in company with Mr S. V. Wood, jun., and later on with Mr. Whitaker, that led to the conclusion that the pebble-beds were of Bagshot age—a view advanced in 1864 by Mr Wood. Unfortunately the section is now obscured, so that, although the party proceeded to the spot, they were able to see little more than the top rearranged gravel that is now worked at Langtons on the eastern side of the road.

Mr. Woodward remarked that the origin of the pebble-beds was a matter of some interest, for they consisted of marine shingle derived from the waste of Chalk cliffs that probably existed in Bagshot times far away to the west or north-west of the district. They showed, at any rate, as did other Eocene pebble-beds, that the Chalk must have been upheaved locally so as to form land during Eocene times, although, as pointed out by Mr. Whitaker, over large areas the Chalk beneath the Tertiary strata presents no signs of disturbance, the bedding of each being conformable.

Mr. Monckton differed from Mr. Woodward as to the marine origin of these Warley pebble-beds, and also as to their being of Bagshot age. He believed that they are mainly *débris* from Bagshot or more recent pebble-beds which had been collected in their present position by various denuding agents. The place at which they are now seen formed at the time of their deposition the bottom of a valley, which in the course of time and in the further progress of denudation has become the top

* See Whitaker's 'Geology of the London Basin,' p 324.

of a hill, the mass of pebbles having served to protect the sandy beds on which they rest. In support of his opinion, he pointed out the irregular manner in which the gravel has been deposited and the presence of subangular flints, several of which were found by Mr. Herries at a considerable depth below the surface, and in that part which Mr. Woodward considered to be undisturbed.

The question, therefore, of the occurrence of Bagshot pebble-beds *in situ* was left "*in statu quo*."

It should, however, be mentioned that in 1868 Mr. Wood suggested that the pebble-beds might be Pliocene; at the same time he maintained that they were quite distinct from the "Gravel of the Higher Plain" (Pebble-gravel).* Again, in 1880, Mr. Wood spoke of the beds as "either of Bagshot or, more probably, of Diestian age."† He appears always to have looked upon them as marine.

The sections at present show mainly the reassorted surface of the Bagshot pebble-beds—a feature recognized during the Geological Survey,‡ although, as remarked by Mr. Woodward, it was not found possible to separate on the map the disturbed from the undisturbed pebble-beds in the areas where the two occurred in conjunction.

The party then proceeded by way of Brook Street to Weald Park, where they were met by the owner, Mr. Tower, who conducted them to the site of an old encampment. Mr. Chancellor, the Mayor of Chelmsford, pointed out the commanding position of the camp, which, he thought, might have been a temporary earthwork thrown up to defend the approach to London. The absence of pottery seemed to show that it had not been inhabited for any long period.

There was no wall or ditch on the park side, but on the other side part of the vallum formed the bank of a field.

As in many other instances, a road runs through the middle of the camp, in this case in a north and south direction.

By kind permission of Dr. C. R. Taylor, an opportunity was afforded of visiting the brickyard north of the railway-station, where there are sections of the passage-beds between the London Clay and Bagshot Sands. The sections show an

* 'Quart. Journ. Geol. Soc.,' Vol. xxiv, pp. 465, 466.
† *Ibid.*, Vol. xxxvi, p. 473.
‡ 'Geology of the London Basin,' p. 322.

alternation of sands, loams, and clay, but they are not so extensive as in a brickyard east of the Station Road that was open during the time when the Geological Survey was made.*

Most of the Members accepted the invitation of Mr. and Mrs. Tower to Weald Hall, where a plentiful tea was provided; while a small party found their way to the White Hart, at Brentwood, and terminated the proceedings by an inspection of that interesting old hostelry.

REFERENCES.

Geological Map, Sheet 1, N.W.

Ordnance Map, New Series, Sheet 257.

WHITAKER, W.—'Memoirs of the Geological Survey,' Vol. iv, pp. 320-328. (Notes by H. B. Woodward and F. J. Bennett.)

MONCKTON, H. W., and HERRIES, R. S.—"On some Bagshot Pebble-beds and Pebble Gravel." 'Proc. Geol. Assoc.,' Vol. xi, p. 13.

EXCURSION TO IGHTHAM (KENT).

SATURDAY, JUNE 1ST, 1889.

Directors: Prof. J. PRESTWICH, D.C.L., F.R.S., and W. TOPLEY, F.R.S.

(*Report by* W. TOPLEY.)

The object of this Excursion was to examine the gravel beds at and near Ightham, from whence a large collection of flint-implements has been made during the last ten years by Mr. B. Harrison. The gravels are partly on the watershed of the Darent and the Shode (a tributary of the Medway), partly within the valley of the Shode itself.†

The watershed referred to is 320 feet above mean sea-level (O.D.). The Shode falls to about 120 feet above O.D., near Shipbourne, and near here there are gravels at 150 feet above it, at 270 feet above O.D. The most important patch of gravel is at Highfield, just east of Ightham. The surface here is 320 feet above O.D., and 60 feet above the Shode. The gravel here is over eight feet in thickness. Other important patches are at Fane Hill and Bayshaw, near Oldbury, and at Coney Field, on the opposite bank of the stream. These places range from 300 to

* See 'Geology of the London Basin,' p. 322.

† These gravels are fully described by Prof. Prestwich in 'Quart. Journ. Geol. Soc.' for May, 1889, p. 270.

330 feet above O.D. Remnants of gravel terraces are scattered about elsewhere, from nearly all of which implements have been obtained, over 400 having been found by Mr. Harrison.

The gravels lie for the most part on the Lower Greensand, but partly on the Gault. The Gault, as usual, forms a flat, narrow plain, but the Folkestone Beds rise into bold hills, the most prominent being that on which Oldbury Camp stands. The "Ightham stone,"* a peculiar variety of Sandstone, cemented by chalcedonic silica and coloured by silicate of iron, occurs here; the outcrops of it being visited.

The Members of the party alighted at Kemsing Station and walked to Broomsleigh, where they were most hospitably entertained by Mr. Thos. Johnston; they then walked to Oldbury Hill to examine the fine camp and the sections around it. On the north-east side of the camp are the remains of what are believed to be "Rock-shelters;" and the importance of having these fully explored was much discussed.†

From Oldbury the party walked north to examine the gravel-pits, full explanations being given by Prof. Prestwich and Mr. Harrison.

At Ightham Mr. Harrison's large collection was inspected, and then, after visiting the gravel at Highfield, the party took train for London at Ightham Station.

ORDINARY MEETING.

FRIDAY, JUNE 7TH, 1889.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—J. M. Collett, F.C.S.; W. Richards, F.C.S.; Dr. R. Schäfer, Ph.D.; P. O. Wilson, F.G.S.

* This rock and other hard beds of the Lower Greensand in the neighbourhood are described by Prof. Bonney, 'Geol. Mag.,' July, 1888, p. 297.

† At the last meeting of the British Association (Newcastle, September, 1889) a committee was appointed (Prof. Prestwich, President, and Mr. Harrison, Secretary) to assist in the exploration of these rock shelters, and a grant of £16 was placed at their disposal for this purpose.

The following papers were then read :—'Notes on the Artificial Unmaking of Flints,' by T. Hay Wilson.

'The Geology of Upton and Chilton in Berks,' by A. J. Jukes-Browne, B.A., F.G.S.

Specimens were exhibited by Mr. T. Hay Wilson in illustration of his paper.

Professor Boulger exhibited a copy of Buchoz's 'Les Dons Merveilleux et diversement coloriés de la Nature dans le Regne Mineral,' Paris, 1782, fol.

WHITSUNTIDE EXCURSION TO THE CRAG DISTRICT,

From Saturday, June 8th, to the following Tuesday, 1889.

Directors: W. Whitaker, F.R.S., F.G.S., of the Geological Survey, and Dr. J. E. Taylor, F.L.S., F.G.S., Curator of the Museum, Ipswich.

(*Report by* Mr. Whitaker.)

A number of Members left Liverpool Street Station with Mr. Whitaker on the morning of Saturday, June 8th, for Southwold; and in the afternoon the party, after taking up quarters at the Swan, walked out along the coast northward.

A pit in the cliff just outside the town, which once gave an interesting section of Glacial Drift, with a little shelly Crag at the base, was found to be overgrown, and the Director could therefore only refer to his published description thereof.

On crossing the shingle-bar of the Buss Creek it was pointed out that, though this bar is all that separates the creek from the sea, yet the water of the latter flows away from the sea to the river Blyth. The Buss Creek is the remnant of a tributary of the Blyth that once flowed along a valley through land eastward of the present coast, land which has been lost by the rapid encroachment of the sea.

On reaching Easton Bavent Cliff—the village of that name has vanished—the walk was continued along the base, and good sections of the Pebbly series, which hereabouts comes between the undoubted Glacial Drift and the Chillesford beds, were seen, and the changes from gravel to sand were noticed. It was soon seen, however, that from the sea not having acted so

strongly against this cliff as it did some years ago, a talus had accumulated all along the base, and consequently but little of the Chillesford beds was seen, as compared with the fine long section of the past. An unusual occurrence, however, was noted—the presence of a large flint, at least a foot long, near the top of those beds, a little north of the site of the former farm.

When the Director mapped this neighbourhood, for the Geological Survey, in 1878-1879, and for some years later, shelly Crag was well seen, rising up from beneath the Chillesford beds south of the farm, and occurring along the base of the cliff for a long way northward, when it again sinks. Owing, however, to the constant talus, nothing whatever was to be seen of this interesting formation, except for a little sand and a few fragments of shells at one part of the slope; whereas formerly the section was the finest exposure of fossiliferous Crag in North Suffolk or Norfolk.

A very great thickness of Crag has been found in the boring at Southwold (147 feet), far in excess of anything known elsewhere in England.

On reaching the long bar of shingle that separates Easton Broad from the sea it was found that this was breached, and that a strong stream was flowing through. The party sat down on the beach near the gap, and the Director alluded to the peaty remains of a so-called Submerged Forest, which runs under the beach and crops out on the foreshore. This is merely part of the alluvium of the valley-bottom, exposed by the cutting back of the land, and is much more modern than the Forest Bed, for which it had been mistaken, but which does not occur along this particular piece of coast.

The return journey was made along the top of the cliff, and it was shown how great had been the loss of land since the old one-inch Ordnance Map was made.

On Sunday afternoon the party drove out to Covehithe, seeing by the way, at South Cove, a pit in rather sandy Boulder Clay, in which the conversion of that deposit, by weathering and decalcification into a stony loam, was well shown. At first sight no one would have thought the two versions to belong to the same deposit.

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From Covehithe church Members walked to the southern

end of the cliff, which, being almost wholly free from talus (though less so than a few years ago), gives a capital section of the Pebbly series overlying the Chillesford beds. At the southern end the remarkable cohesion given to sand by vegetation was noticed, the soil at the top much overhanging and curving over the face of the low cliff.

Many singular and complicated small contortions in the Chillesford beds were seen, and, on reaching the northern end of the cliff, the piling-up of the broad shingle-flat in front of Benacre Broad in successive "falls" was noticed. On returning along part of the cliff-top, the great loss of land here was pointed out.

On Monday, June 10th, a very early start was made for Ipswich, where a few more Members joined from London, and the Ipswich Scientific Society also increased the number. Train was taken to Felixstow, and then carriage to Bawdsey Ferry—about four miles—on arrival at which place the hitherto persistent rain ceased. After a rough crossing a short halt was made at the yet unfinished Bawdsey Manor, where Mr. Quilter, M.P., had kindly provided refreshments. Then the neighbouring cliff was visited, and our finest section of Red Crag was studied, and the junction of that formation with the underlying London Clay was seen. In many parts there is a sort of terrace along the cliff, in the Crag, so that a rich harvest of fossils could easily be got.

Dr. Taylor drew attention to the fossils of the Crag, to the layer of phosphatic nodules at the base of the deposit (which had been worked near by), and to the general character of the formation. Mr. Whitaker pointed out how the shells had been irregularly dissolved out from the upper part, leaving only a shell-less sand; and he described the landslips, caused chiefly by water percolating through the Crag to the slippery surface of the London Clay beneath, the fallen matter being cleared away by the sea.

The return was made along the top of the cliff, and the peculiar shape of the ground was noticed, the cliff being at the highest part and the slope inland being sharp, so that as the cliff is cut back it will be lower and lower.

In the evening the large party dined at the Golden Lion, and then went to the Museum, where Dr. Taylor guided Members

through the collection for which he has done so much, drawing especial attention to the rich local stores, such as the phosphatized mammalian remains and the box-stones from the base of the Red Crag, the fine array of shells from both Coralline and Red Crags, the number of elephants' teeth from Ipswich gravel, Suffolk flint-implements, and various natural-history specimens and antiquities.

Tuesday.—A long and most enjoyable drive was taken from Ipswich through Woodbridge and Chillesford to Orford, in the course of which wide spreads of Common-land were seen, illustrating the natural state of Southern or Low Suffolk. These barren heathy lands occur on the sandy and gravelly plateau through which the valleys are cut.

Soon after crossing the Deben, near Eyke, a halt was made, and a section was seen (from the carriages), which Dr. Taylor thought to be a junction of Glacial Sand with Red Crag. Opinions, however, somewhat differed as to how high the Red Crag reached up, some folk holding that all the sand belonged thereto, with the exception of the gravelly top part.

A halt was made at the Oyster, Butley, whence the party walked to the fine Crag pit a little eastward. Inasmuch, however, as this section, and the others afterwards visited, were described by Dr. Taylor in the account of the Whitsuntide Excursion in 1877,* there is no need to say more of them now.

The pits at Chillesford Church were next visited; then the Coralline Crag pit between Sudbourn Hall and the church, remarkable for the long tubular borings in the stone; then the shallow pit close to Sudbourn Hall, noted for the abundance of Coralline Crag shells; and, lastly, the pit less than a mile E.N.E. of the church, where the junction of the Red and Coralline Crags was seen. The upper part of the Coralline Crag is a peculiar soft limestone, largely made up of Polyzoa (from an old name of which the term coralline is taken). Some of the old pits in the village of Sudbourn are very picturesque, the vertical walls being beautifully weathered and overgrown with lichens.

Other good pits may be seen near Orford (about 1 mile S.). From the ruins of the old castle here there is a view of the

* 'Proc. Geol. Assoc.,' Vol. v, No. 3, pp. 111-112.

wonderful accumulation of beach that separates the river Alde, or Ore, from the sea for many miles.

After a good dinner in the Keep of Orford Castle the party drove back to Ipswich, partly by another route, and the Londoners bid farewell to their friends of the Ipswich Scientific Society, to one of whom, Mr. Henry Miller, they were so much indebted for the excellent arrangements that he had made.

REFERENCES.

The Maps and Memoirs of the Geological Survey relating to the district having been published, and of late years, there is no need to refer to other works, except to note that a general "Sketch of the Geology of Suffolk" has been given by Dr. J. E. TAYLOR, in 'White's Gazetteer of the County,' 1884, and that the various divisions of the Crag are described in great detail in the important papers by Prof. PRESTWICH ('Quart. Journ. Geol. Soc.,' Vol. xxvii, pp. 115, 325, 452).

The Geological Survey Works are as follows:—

For Southwold.

Map—Quarter-sheet 49, N.

'The Geology of Southwold and of the Suffolk Coast from Dunwich to Covehithe,' pp. vi, 87, with a coloured folding plate of the cliff-sections. By W. WHITAKER. 1887. Price 2s. 6d.

For Ipswich, &c.

Maps—Quarter-sheets 48, N.E. (Ipswich and Felixstow), 49, S. (Aldborough), and 50, S.E. (Orford and Chillesford).

'The Geology of the County around Ipswich, Hadleigh and Felixstow,' pp. vii, 156. By W. WHITAKER. 1885. Price 2s.

'The Geology of the County around Aldborough . . . . Orford,' etc., pp. vi, 56. By W. H. DALTON. 1886. Price 1s.

EXCURSION TO HIGHAM.

SATURDAY, JUNE 22ND, 1889.

Director: F. C. J. SPURRELL.

(*Report by* THE DIRECTOR.)

On leaving Higham Station, where the junction of Chalk and Thanet Sand, covered by Brickearth, was seen, the party proceeded to Higham Churchyard, where the Director described the geology of the marshland of the Thames. He also pointed out the sites of the extensive Roman potteries of the neighbourhood. Passing by the little inn still known as the Old Ferry House, the party traversed the marsh northward over the causeway or bridge, as

such places were called in early times, to the site of a block-house, whose foundations of bricks and mortar, etc., on piles, lie now three feet below the Salting surface, and which is nearly washed away. The block-house may have been, as is probable, erected at the time of the two block-houses at Gravesend and Tilbury, in Henry VIII.'s time; but it is certain that it was renovated or rebuilt by Elizabeth at the time of the Armada. The causeway abuts on the shore opposite East Tilbury, and was in mediæval times the line of crossing the Thames from the whole district of East Anglia and the North. During the Roman occupation and earlier, the marsh was inhabited by the Romans and the Britons who worked on the potteries. It is likely that this spot is the one spoken of by Diodorus as being the place where Plautius first crossed the Thames in A.D. 43, where that river "disembogues itself into the ocean, and becomes an estuary at high tide," the tide such as is now seen at London being, 1,800 years ago, some twenty-five miles or so lower down the river, as shown by evidence detailed on the spot, and already printed in the 'Proceedings' of the Association.*

Referring to the history of the embankments of the river, the spot was described as presenting every variety from the most ancient to the most modern on the Thames. From the most ancient, when no protection against the tide was needed beyond a hard causeway across the marsh, to those constructed at various times, when carelessness or the inroads of the sea and storms broke down the walls, and to the latest endeavour to face the river with an even and regular bank. The Director furnished the party with a plan of the ancient walls of the district, and in this was made an effort to show the relative ages of different sections of the walls. All the walls on the river were of later date than those in the lower reaches. All began by the protection of property on the earth-land foot, and extended piecemeal into the marsh and swamps, so by degrees pushing forward the frontage by a junction of the intervals between salient points. This process being frequently interrupted has produced in some places great irregularity in outline, without, however, preventing the diligent observer from perceiving that the process above-mentioned has in all cases been followed. The popular idea that the present tide-walls at the

* *Vide supra*, 'Proc. Geol. Assoc.,' Vol. xi, p. 210, *et seq.*

water edge were all the result of one effort is the result of ignorance, since there are other obsolete walls which preceded them further inland, and the existing walls are not uniform, presenting irregularities in direction, in form, and construction, which precludes any belief in their singleness of design. In the Roman period they were not formed, nor wanted, above Tilbury. In early Saxon times, even if wanted, they were not constructed, except perhaps in a few instances of small area; and in later Saxon times the evidence of documents such as we have, is against enclosure. Even in 1300 A.D. in an Inquisition on the property of Cooling (near Higham) there is mentioned "300 acres of Saltings pasture" with "15 acres of meadow on the Saltings," each worth 6d. an acre, an excellent evidence of the proportion as to area of enclosed to salt marsh; and of the slight inducement to embank, if the value did not increase, as we see was the case. At Cooling, also, it should be noted that the difference between salt and enclosed marsh is much more marked in value than higher up the river. Therefore it was clear that the embankments were the result of individual enterprise; and that in anything like their present regularity, they are of very modern date. The party proceeded to Cliffe, under the ancient cliffs, whence the name is derived, and having spent the whole afternoon on the marshland, returned to town from Cliffe Station.

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EXCURSION TO TOTTERNHOE AND IVINGHOE.

SATURDAY, 29TH JUNE, 1889.

(In conjunction with the Hertfordshire Natural History Society.)

Director: JOHN HOPKINSON, F.L.S., F.G.S.

(*Report by* THE DIRECTOR.)

The Chalk Rock, the top bed of the Middle Chalk, having been seen at Boxmoor on the 18th of May, this Excursion was arranged to enable Members of the two societies to examine another hard and fossiliferous bed in the Chalk—the Totternhoe Stone—which

occurs near the middle of the Lower Chalk; and also at the same time to gain some knowledge of the peculiar features of the north-western escarpment of the Chalk.

Stanbridge Ford Station, near Dunstable, was the place of meeting, and in the morning a walk of twelve or thirteen miles was commenced here, two waggonettes conveying most of the ladies.

Totternhoe Knoll, on which is a British earthwork, was first ascended. The view from the summit, 524 feet above sea-level, is very extensive in clear weather, but to-day, though fine and warm, moisture in the air caused a haze which circumscribed it. When all were assembled the Director said that he would attempt to give an outline of the principal geological features of the surrounding country, and would then ask others present, who had made a special study of the district, to fill in details.

On a clear day, he said, there would be seen in the distance on the north-west a range of hills gently rising from the almost level plain. These hills mark the outcrop of the Lower Greensand, rising from under the plain, which consists of the clayey beds of the Gault and of the Chalk Marl, the line of division between these beds running about half way between Totternhoe Knoll and Stanbridge Ford Station, and following, at a distance of from half-a-mile to a mile, the first rise of the north-western flank of the hills they were on, from Houghton Regis to Totternhoe, and again past Ivinghoe Beacon on the west. Between the Gault and the Chalk Marl there was usually a narrow band of the Upper Greensand, but it did not appear to be present here. A bed of greenish sand at the base of the Chalk Marl, called the Cambridge Greensand, was really the lowest bed of the Chalk, for it contains fossils of the Chalk, and not those of the Upper Greensand.

The Chalk, formerly divided into Upper Chalk or Chalk-with-flints, and Lower Chalk or Chalk-without-flints, was now divided into Upper, Middle, and Lower Chalk. In adopting this triple division the palæontological zones were recognized and the continental classification was conformed to. The Upper Chalk was left as it was, and it represents the *Senonian*; the Chalk below was divided into Middle Chalk, representing the *Turonian*, and Lower Chalk, representing the *Cenomanian*, and where this last division is made there was the greatest palæontological break in the whole of the Chalk.

Their walk was commenced on the Gault, the Chalk Marl was

then passed over, and then the whole of the Grey Chalk, the last 20 or 30 feet of the ascent being up an artificial mound. The Totternhoe Stone also was crossed, for it occurs between the Chalk Marl and the Grey Chalk. After leaving the Gault, therefore, the whole of the Lower Chalk here represented had been traversed; and presently would be seen in the quarries below a section of the Totternhoe Stone and Grey Chalk. This, however, was partly white, and here about the upper half was so. The Chalk Marl was about 70 or 80 feet thick, the Totternhoe Stone at least 20 feet, including when present its middle bed of soft chalk, and the Grey Chalk about 80 feet, giving a thickness to the Lower Chalk here of about 170 or 180 feet.

Near the top of the hill above the quarries there was another hard bed called the Melbourn Rock, which forms the base of the Middle Chalk. Then, forming a great part of the Downs up to from about 700 to 720 feet in altitude, was the great mass of Chalk-with-few-flints: its flints being chiefly near the top, and not occurring in layers as in the Upper Chalk. A third hard bed, called the Chalk Rock, forms the summit of the Middle Chalk. It contains many fossils, the prevailing forms being Gastropoda, which are comparatively rare elsewhere in the Chalk. The Melbourn Rock was here about 10 feet thick, the Chalk Rock five feet or more, and the white chalk between these beds from 220 to 230 feet. It had hitherto been stated to be 350 feet in thickness in Beds and Bucks,* but from aneroid measurements he felt sure that here this was at least 120 feet too great.

Here and there in the course of their walk springs would be seen issuing from the Totternhoe Stone, which might easily be traced as it winds round the hills almost at their base. There was no such indication of the Melbourn Rock, nor of the Chalk Rock, but the outcrop of the latter might be easily followed. The Five Knolls seen on the south were just below it: a little higher, to the right or westward, it crops out, and it forms the top of the escarpment for nearly a mile: at Kensworth Hill it is capped by nearly 80 feet of the Upper Chalk, and it keeps near the top of the ridge until it recedes from view; and finally, it caps, as an outlier, the projecting point still further west, which is Ivinghoe Beacon.

* See 'The Geology of the Neighbourhood of Cambridge,' by W. H. Penning and A. J. Jukes-Browne, p. 21 (1881). The reference here to "Whitaker, 1865, 1872," Mr. Jukes-Browne informs me, is to his section in his memoirs given in the References on p. lxxxi.

Flexures in the Chalk, as shown in the section on p. lxxviii, were then alluded to, and outliers of the Middle on the Lower Chalk, and of the Lower Chalk on the Gault, were pointed out, showing what a vast amount of chalk must have been removed by denudation, and how the Chalk hills, having at one time been so much higher than they are now, might have caused a greater rainfall in past ages, and therefore a greater amount of denudation.

Mr. James Saunders, of Luton, then added some remarks about the Totternhoe Quarries. He said that it was a curious fact that although the Totternhoe Stone had been known ever since Norman times as a building-material, yet it was not until within the last twenty years that the overlying Grey Chalk had been valued for the purpose of lime-burning. It was considered to be as good as any rock in the country for the production of grey lime, which was worth much more than white lime. The demand was now so active that 18 or 20 kilns were in almost constant use, each holding about 120 tons of material worth £90 to £100. It would be noted on examining the quarries that the Grey Chalk was of considerable thickness, probably over 70 feet, and that at the base it was dark grey and in massive blocks, passing up gradually into a much whiter condition, where it broke up into smaller portions. At the present time the Totternhoe Stone was only exposed in one or two small sections, which would be inspected. But whether it was to be regarded as forming two distinct beds, or one thick mass gradually changing in the entire thickness, it was certain that the lower and upper parts were lithologically distinct, the former being the only portion adapted for building purposes, whilst the latter was used for making hearth-stones. The Company working these quarries had orders for eighty-thousand cubic feet of the building-stone, partly to be employed in the restoration (or rather rebuilding) of parts of St. Albans Abbey. Much of the bed would therefore be exposed after a time, when further information as to its composition might be obtained.

Mr. Saunders then read extracts from letters he had recently received from Mr. Whitaker and Mr. Jukes-Browne. Mr. Whitaker said that westward the Totternhoe Stone dies out, and in Wilts, etc., the Chalk Marl cannot therefore be divided from the rest of the Lower Chalk, the same being the case generally in the south. Mr. Jukes-Browne wrote that he saw a fine section here in 1884, but did not recognize two beds of the stone. The

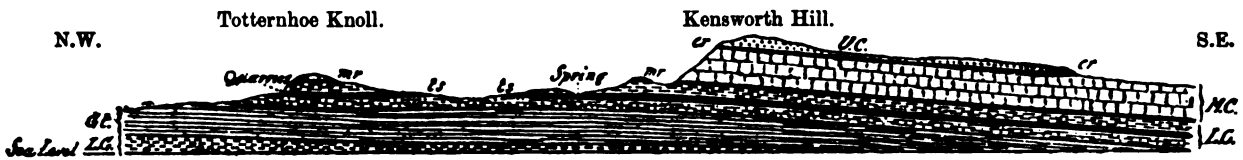


FIG. 1.—Section through Totternhoe Knoll and Kensworth Hill, near Dunstable.

U.C. Upper Chalk. *M.C.* Middle Chalk. *L.C.* Lower Chalk. *Gt.* Gault. *L.G.* Lower Greensand.

cr. Chalk Rock. *mr.* Melbourn Rock. *ts.* Totternhoe Stone.

Horizontal Scale: 1 inch = 1 mile. Vertical Scale: 1 inch = 1320 feet (¼ mile).

base was not visible, being four or five feet below the exposed part, according to the workmen, and he estimated the thickness of the stone as 20 to 25 feet.

Mr. Worthington Smith, of Dunstable, then drew attention to the pre-historic antiquities of the neighbourhood. They were standing, he said, upon the beacon in the midst of an ancient British camp, the earthworks of which he pointed out. The hollow places around them, of which there were at least fifty in that camp, were the sites of the huts of the early inhabitants. In the neighbourhood of Dunstable he had excavated some of these, and found flint-implements and flakes, and in one case a skeleton. Close by was a square camp, which, as its shape indicated, was of Roman origin.

Descending the beacon hill on the south side, the party walked round the Roman Camp, from the furthest end of which the mound is very conspicuous, though all that is seen of it here, is artificial. From the Camp a further descent was made into the quarries, where a fine section of the Grey Chalk was seen, and a few exposures of the Totternhoe Stone were examined. Some time was then spent in searching for fossils, and several were procured.

Continuing the walk on the Downs, the disused workings, now grass-covered, were pointed out; and a little further on was seen the circular enclosure known as Maiden's Bower, the site of the old British town of Durocobrivæ, now a ploughed field with the remains of the ancient rampart forming a high bank around it. The road now being traversed was the Watling Street, and near this point it is crossed by the Icknield Way. Leaving Dunstable on the left, the Watling Street passes the Five Knolls, a series of Roman tumuli, and here all assembled to partake of luncheon.

From the quarries to this point the walk had been entirely on the Middle Chalk, in which were now seen, on the Dunstable side of the Knolls, extensive pits worked for lime; just below, looking towards Totternhoe, a coomb was traced downwards to where several springs issue from the Totternhoe Stone, the coomb therefore here merging into a river-valley; and towards Kensworth Hill, shallow openings, scarcely pits, by the roadside, exposed the Chalk Rock, which had been worked for road-metal.

This direction was now taken, and on arriving at the highest point of Kensworth Hill, 800 feet above sea-level, a few further remarks on the geological features were made by the Director, and

the party again separated, those riding returning to the Five Knolls, and thence by the Icknield Way to Ivinghoe Beacon, and the walkers continuing on the Downs and following the outcrop of the Chalk Rock to a pit by the road near the top of the escarpment above Valence End Farm. Here at one time a fine section of the Chalk Rock was to be seen, but it is now covered up by rubble, the pit showing only the base of the Upper Chalk, and the next pit just below showing the upper beds of the Grey Chalk.

A descent was made down the steep face of the escarpment, past the site of old British huts, then the fields were crossed into a coomb, and a small stream issuing from one of the numerous springs in the Totternhoe Stone was followed as far as the Icknield Way, under which the stream flows.

On the way to Ivinghoe Beacon two other streams were seen rising from springs in the Totternhoe Stone, one of them proceeding from a most picturesque coomb just under the Beacon. The summit of this hill is 762 feet above sea-level, necessitating a climb of 350 feet from the Icknield Way—from the Totternhoe Stone to above the Chalk Rock which caps the hill as an outlier—and here the whole party again assembled.

The remainder of the walk presented nothing of special geological interest, but the stroll along Duncombe Terrace (by permission) was the most enjoyable portion of the day's walk. This is a private road which winds along the hill-side, keeping to the same level, for about three miles, through woods with an opening here and there disclosing glimpses of the valley below and of the wooded hills beyond it. The private portion of this road ends at Moneybury Hill, where a Roman tumulus was inspected, and a little further on was seen the monument to the Duke of Bridgewater, Father of Inland Navigation, a granite column 200 feet high, erected in 1832. From this point a descent was made to the village of Aldbury, where tea was partaken of, after which the walk was continued for another mile down the valley to Tring Station.

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ORDINARY MEETING.

FRIDAY, JULY 5TH, 1889.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentleman was elected a Member of the Association:—C. F. FOX.

The following papers were then read:—'The Geology of North-West Cumberland,' by T. V. HOLMES, F.G.S., President.

'The Geology of the Eden Valley District,' by J. G. GOODCHILD, F.G.S., etc.

'On the Estuary of the Thames and its Alluvium,' by FLAXMAN C. J. SPURRELL, F.G.S., etc.

Prof. BOULGER exhibited a series of photographs, by Mr. S. G. Payne, of Aylesbury, of some of the chief sections in that district, showing junctions between Portlandian and Purbeckian at Hartwell and at Cuddington, the false-bedded Neocomian sand at Stone, Dinton Castle, etc.

Mr. WILLIAM WHITE exhibited a slab of Lias, from Wilmcote, Warwickshire, belonging to Rev. H. E. Lowe, containing a fossil which had been once thought Coleopterous. Mr. A. SMITH WOODWARD, F.G.S., at once determined it as the head of the fish *Leptolepis* seen from beneath and showing the branchiostegal rays.

EXCURSION TO LIMPSFIELD (SURREY).

SATURDAY, JULY 13TH, 1889.

Directors: Prof. J. PRESTWICH, D.C.L., F.R.S., and W. TOPLEY, F.R.S.

(*Report by* MR. TOPLEY.)

This Excursion was intended to supplement that to Ightham on June 1st (see p. lxvi), and to give an opportunity of examining gravels at the western end of the Darent Valley, partly within that valley, partly on the watershed between the Darent and the Medway.

The gravels are much more important, in thickness and area, than those near Ightham; both, however, have this point of interest in common, that they have yielded large numbers of Palæolithic implements.

Mr. A. M. Bell, by whom the implements have chiefly been found, received the party at his house (Manor House, Limpsfield), and exhibited his collection. Here the Members were joined by Prof. Prestwich and Mr. Leveson Gower, of Titsey Park. They then proceeded to Limpsfield Common, where the most important deposit of gravel occurs. This gravel lies at 500 feet above the sea.* A little to the south there is a considerable quantity of brickearth, also on the watershed; the lower part of this is perhaps formed of re-arranged clayey bands of a Lower Greensand (equivalent of the "Sandgate beds"), but the upper part is a true brickearth, deposited from water.

The more important areas, as regards implements, are a little to the east of the places just named, where the gravels are not now so extensive; indeed, it seems to be generally near the bottom of a gravel that most implements occur; and hence they are found most abundantly where the gravel has been in great part removed by denudation.

* Since the visit of the Association, Mr. Bell has obtained several implements out of gravel taken from this pit, and has himself found one *in situ* near the bottom of the gravel.

On Limpsfield Common, Mr. Leveson Gower pointed out the remains of British tracks and embankments. Walking eastwards, and passing by other implement-yielding gravels, the party arrived at Westerham. Here tea was provided. Some Members went to London from Westerham, others returned up the Darent Valley to take the return train at Limpsfield.

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EXCURSION TO UPTON AND CHILTON.

Saturday, July 20th.

Director: W. Whitaker, F.R.S., F.G.S., of the Geological Survey.

(*Report by* The Director.)

The morning was so stormy in London that the President was almost alone in his journey down, being, however, joined by the Director at Reading. The unusually select character of the party enabled the whole to do more than the usual amount of walking, and in perfect comfort, the rain leaving off at the right time.

On reaching Upton Station the Members walked along the line, examining the long cutting, which for some way is in the Lower Chalk, with some peculiar hard beds, and then shows a great mass of freshwater Drift near Chilton. As the whole of these beds have been described in detail by Mr. Jukes-Browne, in a paper written expressly with a view to this Excursion,* it is needless to say more here.

There being plenty of time disposable, the party walked up

* 'Proc. Geol. Assoc.,' Vol. xi, No. 4, pp. 198-209.

the grassy slope of the Chalk Escarpment to the south, and, on reaching the top, turned westward and went for some way along the grass-grown Ickleton Street, gradually rising to the point on which the great barrow known as Cuckhamsley Knob is placed. Here Mr. Parker gave a most interesting account of this object of antiquity.*

Tracks were then made obliquely a little way down the face of the Escarpment to where the Chalk Rock was being worked, in a shallow pit, for road-metal. The section was found to be a good one, well showing the peculiarities of this remarkable bed, which divides the Upper from the Middle Chalk. It is a hard cream-coloured limestone (here a few feet thick), passing downward into hard chalk, but ending sharply at top, where it is crowded with irregular-shaped green-coated nodules. As regards fossils, it is fairly rich, and differs from the rest of the chalk in yielding Gastropods in some abundance, pointing to a shallowing of the sea. One of the specimens found, a cast of a *Pleurotomaria*, was green-coated, like the nodules. The marked joint-planes of this bed were noticed, and many fossils were taken.

The return walk was made along the foot of the Escarpment, and then through Chilton to Upton Station. On getting to Didcot it was unanimously agreed to dine at the hotel there, and this part of the programme, like the rest, was carried out with great satisfaction, perhaps enhanced by a feeling of pity for those Members who had not joined.

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* See 'Proc. Geol. Assoc.," Vol. v, p. 138.

EXCURSION TO NORTH-WEST CUMBERLAND AND EDENSIDE.

AUGUST 5TH TO 10TH, 1889.

Directors: The PRESIDENT and Mr. J. G. GOODCHILD, F.G.S.

(*Report by* THE DIRECTORS.)*

Most of the Members attending this Excursion arrived at Carlisle on the evening of Saturday, August 3rd. On the afternoon of Sunday, August 4th, many visited the beautiful village of Wetheral about five miles east of Carlisle. Before descending to the banks of the Eden, the delightful views from the lofty railway-viaduct were much admired. Looking up the river-valley (towards the southern side of the viaduct) the stream is seen to flow in a beautifully-wooded gorge of St. Bees Sandstone, the gateway of Wetheral Priory being visible on the right, while on the left a small portion of Corby Castle appears among the trees. North of the viaduct the valley widens: broad alluvial flats are seen on each side of the stream; and the spectator surveys a broad, well-wooded, fertile plain, the well-known Scottish heights, Langholm-Monument Hill, Burnswark, and Criffel, being conspicuous in the blue distance. This change in the character of the river-valley is due to the fact that the dip of the St. Bees Sandstone is north-westerly, or down the stream; while a little below the junction of Eden and Irthing the very soft Kirklinton Sandstone overlies the harder rock of St. Bees. Also, between Wetheral and Carlisle the easily-eroded Glacial Drift thickens very much, so that, instead of hard Sandstone cliffs 70ft. or 80ft. above the river (as at Wetheral), at Carlisle the Permian-Triassic beds seldom attain a height of more than 7ft. or 8ft. above the level of the Eden or Caldew.

Leaving the viaduct, the party walked past the gateway-tower of Wetheral Priory to the banks of the Eden, visiting on their way the artificial caverns in Red Sandstone about half-way up the river-cliff, which are known as St. Constantine's Caves. They are about 40ft. above the river-bed, and must always have been very difficult of access against the will of the occupier. It may be

* Mr. Goodchild is responsible for the account of the Excursions on Thursday, Friday, and Saturday; the President for the rest.

worth mentioning here that caves similar in position, and also in Red Sandstone, were accidentally discovered about 30 years ago at Crailing, in Roxburghshire, on the north bank of Oxnam River, a tributary of the Teviot. They are described by Mr. D. Milne Home in the 'Proc. Berwicksh. Nat. Field Club' for 1856-1862, p. 316, who also mentions the Jed, above Jedburgh, Hawthornden, Crickup Linn, Dumfriesshire, Ancrum, and other places, as spots where there are artificial caves in Red Sandstone. In the case of the Crailing Caves no tradition about them was told in the neighbourhood. The Wetheral Caves are known to have existed in the time of Henry II. In addition to the name of St. Constantine's Caves, they are sometimes known as Wetheral Safeguard. Though possibly at one time the abode of a hermit, it seems more likely that they were constructed as places of security for valuables in troubled times.

Leaving St. Constantine's Caves, the party walked as far as Brackenbank, where a fault crosses the stream, having a downthrow to the north. South of this line of fault the Penrith Sandstone may be seen here and there along the course of the Eden, though nowhere visible north of it in Cumberland.

The walks along the Eden at Wetheral and Corby have long been famous for their beauty. In the last century David Hume refers to them in the following lines:—

> "Here chicks in eggs for breakfast sprawl,
> Here godless boys God's glories squall,
> While Scotsmen's heads adorn the wall;
> But Corby's walks atone for all."

We were fortunately able to enjoy the scenery of the Eden hereabouts, free from any unpleasant recollections of Carlisle eggs or anthems, or of the adornments of its walls.

Monday, August 5th.—The early morning was dark and rainy, so that it was thought better to go to Whitehaven by the 10.50 train rather than by that at 9.10. This arrangement had the additional advantages of allowing Members already in Carlisle an opportunity of seeing the Castle and Cathedral, etc., and of giving an additional chance to any who might have arrived by a night-train of joining the Excursion to Whitehaven and St. Bees.

Carlisle was a walled town in 1745, and was besieged and taken during the insurrection of that period, first by Prince Charles Edward, and a few months later by the Duke of Cumberland,

known in history as the Butcher, from the infamous cruelties ordered and permitted by him after the battle of Culloden. But in 1811 the greater part of the wall was removed, and now only a portion of the west wall, overlooking the valley of the Caldew, still remains. Before 1811 the walls of Carlisle may be described as having extended from the Castle at one end to the Citadel at the other, the Citadel consisting of special defensive works which stood where the huge round towers of the Court-houses now stand, close to the Railway (Citadel) Station. From the Citadel the west wall ranged by the gaol and the Great Central Hotel to the west side of the Castle, while the course of the other portion of the wall was from the eastern side of the Castle, by West Tower and East Tower Streets, along Lowther Street to the Citadel. Within the Castle walls there are few buildings of any interest besides the keep, which is very unpicturesque in outline from having been altered by Henry VIII. so as to enable it to bear artillery. The lower part of the keep only is shown. It contains the dungeons in which the prisoners of 1745 were immured. The sight of them was well calculated to make the spectator feel that if our unfortunate fellow-countrymen at Carlisle had any advantage over the inmates of the Black Hole of Calcutta it must have been chiefly one of climate.

The Cathedral is a building of various styles, from Norman downwards. The low tower was once central, but the greater part of the nave was destroyed in 1646. The one feature of unique beauty it possesses is the great east (Decorated) window, which, for a combination of great size with beauty of design, is, perhaps, unrivalled, certainly unsurpassed.

Between 10 and half-past 10 o'clock the weather gave sufficient promise of improvement to warrant our journey to Whitehaven and St. Bees. Arrived at Whitehaven, the party crossed the town, and turning up Albion Street gained the top of the cliff on the southern side. From this point to Barrowmouth they proceeded either along a road ranging about half-way up the cliff-side, and showing a good section of Whitehaven Sandstone on the left, or on a pathway on the edge of the cliff. The beach below, which would have been the best road, from a purely geological point of view, had our time been unlimited, was utterly impracticable under the circumstances, owing to the immense blocks of Whitehaven Sandstone and other rocks with which it is covered, and which would have made progress along it a work of climbing

rather than of walking. Here and there, however, the Director was enabled to point out from the edge of the cliff indications of the unconformity of the Whitehaven Sandstone to the ordinary Carboniferous Rocks on which it rested. The Whitehaven Sandstone was lying nearly flat, but with a very gentle and steady dip southward, in the direction of St. Bees Head, while the dip of the beds below was seen to vary considerably from place to place, an anticlinal fold being very clearly visible at one spot. On reaching Barrowmouth, the party descended to the level of the beach. There the Whitehaven Sandstone was the lowest rock seen, while on it rested a bed of breccia about 3ft. thick. Above the breccia was 10ft. or 12ft. of Yellow Magnesian Limestone, and above that the Red Marls with gypsum were seen passing upwards into the massive Red Sandstone which forms the fine headland of St. Bees. Fortunately the weather had been slowly brightening, and the Isle of Man became visible a little south of west, while an ascent of the steep escarpment of St. Bees Sandstone, a little inland, gave a view over the Carboniferous district east of St. Bees Head, and of many of the mountain peaks beyond. The lateness of the hour at which we started from Carlisle, together with the fewness and inconvenience of the trains from St. Bees to Whitehaven, prevented any attempt to prolong our walk to Fleswick Bay and the village of St. Bees, across the headland.

Tuesday, August 6th.—About nine o'clock in the morning there was every promise of a wet day. Fortunately we had no train to catch, as the railway could only have lent the most trifling assistance towards the carrying out of our programme. About half-past ten there seemed slight signs of clearing up, and we drove from the hotel in the direction of East Curthwaite, feeling that at the worst we could decide to return at any moment, if threatened with heavy and continuous rain. But fortune again favoured the bold, and by the time we arrived at East Curthwaite, at the spot where we proposed to go up Chalk Beck, there was every prospect of a fairly fine day. The beck, however, was much fuller of water than usual, and some little delay was occasioned by the necessity of placing our own stepping-stones at certain spots where it was necessary to cross the stream, and desirable to avoid slips into the water. Some good sections of St. Bees Sandstone were seen, and the spot now known as "Tom Smith's Leap," at which a Roman inscription formerly existed, was pointed out. In Gilpin's 'Observations relative chiefly to Picturesque Beauty, made in the year 1772,

on Several Parts of England, particularly the Mountains and Lakes of Cumberland' (2nd Ed., 1788, Vol. ii, p. 101), are these remarks :—

"Between Rose Castle and Wigton the country abounds with the relicks of Roman incampments. At a place called Chalk-cliff (which, by the way, is a cliff of red stone) this legionary inscription is engraved in the native rock :—

LEG $\overline{\overline{\text{II}}}$ AVG
MILITES FEC
COH III COH IIII."

Above Tom Smith's Leap, the Sandstone soon becomes less massive and more flaky and shaly, and the quarries disappear. Above the marked easterly bend of the Beck, close to the old limekiln, the St. Bees Sandstone begins to climb the bank on each side, and Carboniferous Sandstone and Shale are seen in the bed of the stream. The junction between the two formations was visible near the path on the western side of the beck, about half-way up the steep bank, the contrast between the brick-red colour of the Permian-Triassic beds and the whitish or purple-grey of the Carboniferous rocks being very manifest. Then (as shown in the section from Chalk Beck across Warnell Fell, Fig. 2, p. 233) Carboniferous strata occupied the whole of the ground from the bed of the beck to the top of the bank for a short distance; but before the road from Rosley Rigg to Near Welton could be reached, a fault, ranging nearly east and west, and having a downthrow to the south, was seen to cross the beck, its effect being shown in the appearance of old quarries in the lower beds of the St. Bees Sandstone in the field on the northern side of the road. (See Chalk Beck and Warnell Fell Section.) A curious surface-contortion was visible in one of the old pits in this field.

It had been hoped that time would have permitted some examination of the Carboniferous rocks higher up Chalk Beck before visiting the thick limestones at Parkhead on Warnell Fell. But it soon became evident, on regaining our carriages in the Rosley Rigg and Near Welton Road, that it would be more prudent to drive straight to Warnell Fell. This we did, and, sending the carriages on to Caldbeck, examined the thick limestone at Parkhead. After some little time had been spent in the collection of fossils, the party proceeded along the footpath, down the hillside in a south-westerly direction, to the village of Caldbeck. After tea

at the Oddfellows' Arms (kept by Mrs. Cape), the Howk was visited. The Howk is somewhat higher up the stream, known as the Caldbeck, than the inn, the distance being rather more than a quarter of a mile. The beck, in cutting through a thick bed of limestone, has worked out a passage at this spot so as to leave a natural limestone bridge above a waterfall, while close by are a cavern and a very large pothole, also the work of the stream. The whole makes a very beautiful and interesting scene. Many years ago a farmer attempted to close the footpath crossing the Caldbeck at this spot by blowing up the natural bridge, but was compelled to restore it. This has been done in such a way as to preserve the original appearance as far as possible.

The return journey to Carlisle was made *vid* Hesket-Newmarket, Raughtonhead, and Rose Castle. It was somewhat rainy, but comparatively little inconvenience resulted therefrom at that part of the day's excursion. About midway between Caldbeck and Hesket-Newmarket the Director called attention to the fine, bold hillside north of the Caldbeck, pointing out the well-marked escarpment of the Parkhead Limestone at the top of the hill, and those of two other thick limestones between it and the stream. He explained the reason why, in descending the hill from the Parkhead Limestone to the village of Caldbeck, they had not crossed the two lower limestones. This was to be found in the existence of a fault, the position of which was obvious from their present point of view being marked by the ending off along a certain line of the steep banks made by the limestone escarpments. They had crossed this fault soon after leaving the large Parkhead quarry, their journey thence to the village having consequently been made on the downthrow side over beds mainly consisting of sandstone and shale, such as occur on Warnell Fell above the thick limestones.

Wednesday, August 7th.—The early morning gave promise of a fine day. Nevertheless, this was the first day in which the carrying out of the programme was seriously interfered with by rain. About half-past nine o'clock the party drove northward along the road to Longtown. Their first halt was at the bridge over the river Line at Westlinton. There they walked on to the bridge, noticing the cliff of Kirklinton Sandstone, much hidden by the leaves of trees on the western side. Then, descending into the field on the eastern side of the bridge and southern bank of the stream, they inspected the junction of the Kirklinton Sandstone and Stanwix Marls in the steep bank bounding the alluvium, about fifty yards away. Re-

gaining the carriages, they proceeded towards Longtown. The Esker ridge, on the southern side of Arthuret Church, was pointed out, and, indeed, passed through, the road being cut through it. At a spot between Arthuret and Longtown, where a good view was obtainable across the broad alluvial flat of the Esk, the Director stopped the carriages and remarked that the well-known Solway Moss lay behind the belt of trees bordering the somewhat higher ground westward of the low-lying alluvial plain. Gilpin, the writer on the picturesque, already referred to in connection with Chalk Beck, visited this district very shortly after the bursting of the great peatmoss in November, 1771, and has left, in the work before quoted, a graphic description of what he saw and heard of the great catastrophe. This was read by the Director, and some of it is given here. Gilpin states :—

On the 16th November, 1771, in a dark tempestuous night, the inhabitants of the plain were alarmed with a dreadful crash which they could in no way account for. Many of them were then abroad in the fields watching their cattle, lest the Esk, which was rising violently in the storm, should carry them off. None of these miserable people could conceive the noise they heard to proceed from any other cause than the overflowing of the river in some shape, though, to them, unaccountable. Such, indeed, as lived nearer the source of the eruption were sensible that the noise came in a different direction, but were equally at a loss for the cause. In the meantime the enormous mass of fluid substance which had burst from the moss moved slowly on, spreading itself more and more as it got possession of the plain. Some of the inhabitants through the terror of the night could plainly discover it advancing, like a moving hill. This was, in fact, the case; for the gush of mud carried before it through the first two or three hundred yards of its course a part of the breastwork, which, though low, was yet several feet in perpendicular height. But it soon deposited this solid mass and became a heavy fluid. One house after another it spread round, filled, and crushed into ruin, just giving time to the terrified inhabitants to escape. Scarce anything was saved, except their lives; nothing of their furniture, few of their cattle. Some people were even surprised in their beds, and had the additional distress of flying naked from their ruin.

The morning light explained the cause of this amazing scene of terror, and showed the calamity in its full extent, and yet among all the conjectures of that dreadful night, the mischief which really happened had never been supposed. . . .

This dreadful inundation, though the first shock of it was the most tremendous, continued still spreading for many weeks, till it covered the whole plain—an area of 500 acres; and, like molten metal poured into a mould, filled all the hollows of it, lying in some parts 30 or 40 feet deep, reducing the whole to one level surface. The overplus found its way into the Esk, where its quantity was such as to annoy the fish, no salmon during

that season venturing into the river. We were assured also that many lumps of earth which had floated out at sea were taken up some months after at the Isle of Man.

When Gilpin visited the plain it was covered by a thick smoke, the peat having been set on fire with the view of consuming it. He visited, with some difficulty, the spot from which the overflow had taken place, and from which a black mossy fluid still continued to run, and obtained a good view over the flat below showing the course of the eruption. Of this sight he remarks :—

Here and there along this surface the broken rafters of a house, or the top of a blasted tree were seen, and made an odd appearance, rising as it were out of the ground in which they were half sunk. But through the whole waste there was not the least sign left of any culture, though this plain had once been the pride of the country. Lands which in the evening would have let for 20*s.* an acre, by the morning light were not worth sixpence.

On this well-cultivated plain 28 families had their dwellings and little farms; every one of which, except a few who lived near the skirts of it, had the world totally to begin again.

As regards the way in which the plain was eventually cleared of the peaty incubus, Gilpin remarks that fire had little effect, and that the work was at last accomplished by the ingenuity of a man named Wilson.

From the reservoirs formed by a little stream at the highest part of the overflowed ground, he cut channels in various directions to the Esk, and when the water was let off he placed numbers of men by the stream, who rolled into it large masses of mossy earth which had been hardened by the sun.

The stream, of course, conveyed the lumps of peat into the Esk, from which they found their way into the sea. Gilpin's account is described in Hutchinson's 'History of Cumberland' (1794) as "sufficiently accurate," and is largely quoted from. Another account given in Hutchinson mentions "near a thousand acres" as the area overflowed. No human lives are there stated to have been lost, though a certain number of cattle perished. One cow is said to have been saved out of a herd of eight, after having stood sixty hours up to the head in mud. But, "When she was got out she did not refuse to *eat*, but *water* she would not taste, nor could even look at without horror, and discovering all the symptoms of hydrophobia. She is since, I hear, reconciled to it, and likely to recover." ('Hutchinson,' Vol. ii, p. 541.)

After passing through Longtown, and when proceeding along

the road towards Netherby, the Director pointed out the existence of some older alluvial terraces of the Esk, in addition to the great lower flat visible in the distance. The party, on reaching the spot beyond Netherby at which Carurnley Burn crosses the road, left the carriages to view the Kirklinton Sandstone which forms the gorge of the stream from Carurnley Mill to the Esk. Unfortunately it was impossible for so large a party to descend into the gorge close to the mill to see the junction between the Sandstones of Kirklinton and St. Bees; and higher up the stream it was found that since the Directors' last visit to the locality a notice had been placed close to the footpath beside the Burn announcing the prosecution of all trespassers. The reason for this notice speedily appeared, on walking a little distance along this path, in the shape of numerous coops for the rearing of pheasants; and as the contrast between the Carboniferous and Permian-Triassic rocks would be even better displayed on the Line about Brackenhill Tower, it was thought best to retrace our steps and proceed to Hethersgill.

Crossing the Line at Shank Bridge, the carriages drove through Bolton Fell End, leaving the great peat-moss on the right, to Nethersgill. The junction between the Carboniferous and Permian-Triassic beds in the Hetherburn, a little south-east of the Grainhead farm-buildings, was seen, the breccia at the base of the latter series being well shown, owing to the fact that, having recently come into use locally for road-metal, a small quarry had been opened in it. A storm now threatened to interfere with the rest of the programme, and the carriages had scarcely reached the inn at Bolton Fell End when rain began to fall heavily. It continued so long that when signs of clearing appeared it was evident that it would be necessary to give up all thoughts of walking down the river Line from Brackenhill Tower to Cliff Bridge; so the carriages drove straight to Cliff Bridge, and even then only some ten minutes could be spared to enable the party to see the beautiful river-cliff of Kirklinton Sandstone at the Bridge, the junction of that rock with the overlying Stanwix Marls remaining unvisited. The section was much admired by the party, not only on account of the very bright colour of the soft red stone, which was the more striking from contrast with the bright green verdure of the trees, whose branches drooped more or less over the top of the cliff, but also as affording an extremely clear illustration of what is meant by false-bedding. Between Cliff Bridge and Carlisle the route

was through a featureless, drift-covered district, presenting no characters of geological interest, the underlying formation being the Stanwix Marls.

Thursday, August 8th. Appleby, Helton Beck, and Roman Fell.—The first section visited was at Hungriggs Quarry, a short distance north of Appleby Station. Here was seen a good exposure of the Lower Brockram, the basal breccia of the Lower New Red, and therefore of the Neozoic rocks. The Director explained the relation of the Brockram to the Magnesian Limestone above and to the Penrith Sandstone, into which this and the Upper Brockram pass as the rocks trend towards the north-west. The Lower Brockram here lies on the Millstone Grit, but it has formerly overstepped the Coal-Measures of Argill (a few miles to the east of Appleby), and elsewhere in Westmoreland it lies upon various members of the Lower Carboniferous. The Director called attention to the staining of the sandstone and the shale fragments, and to the dolomitization and the local replacement by hæmatite in the case of the blocks of limestone. The mode of arrangement of the constituents suggested that they had been deposited in an inland lake by the agency of floating ice. Just as this statement had been made Mr. Wm. Atkinson discovered a large boulder from the Brockram, which showed unmistakable glacial striæ. This boulder, the first authentic example on record, was carried off by the party taking it in turn, and is to be deposited in the Penrith Museum. Helton Beck was next followed northward. Here was seen the soft bright red sandstone that has set in between the Lower Brockram and the Upper, and that develops, at the expense of the Brockram, into the well-known Sandstone of Penrith. The gradual replacement of the breccias by sandstone was well exemplified by the Upper Brockram, of which good sections are shown along the course of the beck. The sandstones above the Upper Brockram were seen to become progressively less red as they were traced upwards, until they eventually pass into micaceous, saffron-coloured, and grey sandstones of the ordinary type. The Director pointed this out as an indication of diminished salinity, and showed that with a smaller percentage of sulphate of lime in the waters of the old lake, the vegetable remains had not undergone decomposition, but had left traces of their form in more or less abundance. From these plant-bearing strata, the Helton Plant beds, several of the party obtained specimens. They yield, amongst other plants, *Ullmannia selaginoides*, *Walchia piniformis*, *Nœggerathia*

cuneifolia, *Cardiocarpon*, etc. Thin seams of true coal occur also. The Plant beds represent the Marl Slate; the beds below are the equivalents of the Rotheliegende. Following the section still towards the north-east, the geologists crossed several alternations of yellow sandstone, marl, and sandy dolomite, and then reached the local representative of the Magnesian Limestone, which, though thin here, attains to as much as thirty feet in the next parish to the south-east. This limestone forms the highest member of the Lower New Red. It is locally succeeded by a thin conglomerate, which probably coincides with a small unconformity. The party cursorily inspected the Lower Gypseous Marls which here form the base of the Bunter, which graduates upwards into the St. Bees Sandstone. This is well seen in several quarries and natural exposures along the route. It has yielded reptilian footprints ("*Cheirotherium*"), and shows sun-cracks and other features of interest. Higher up the beck, at the foot-bridge by Helton Smelt Mill, the St. Bees Sandstone is abruptly cut off by the Outer Pennine Fault, which has brought the Bunter beds side by side against argillaceous limestones of Bala age. The Director pointed out the chief features of interest at this point, and then, after some of the party had collected Bala fossils, a move was made in a south-easterly direction, so as to examine the Lower Ordovician beds as they are brought up by the dip. The Dufton Pike tuffs of The Seat, which are the next beds below the limestones of the Smelt Mill, were cursorily examined, and the Director pointed out that these were bounded on the north-east by a large fault, which brings some of the alternations of fine tuff and argillite known as the Milburn rocks against them. In these submarine equivalents of the Borrowdale Series the geologists examined a remarkable dyke of micaceous elvanite, containing rhombs of muscovite an inch or more in length. Then another fault on the north-east was crossed, and the party found themselves on a fine series of alternations of avas, tuffs, and ashy mudstones, shales, and sandstones of Bala-age, which were dipping in a general northerly direction. In crossing these towards the south, successively lower beds were reached, until eventually the lowest bed was seen, which was a thick mass of calcareous shale, containing fossils of Lower Bala types. The existence of this important piece of evidence was made known to several well-known geologists by the present writer in 1876. A similar group, perhaps the same strata, has since been discovered by Messrs. Nicholson and Marr at Drygill,

in the Caldbeck Fells. It is probably also the deeper water equivalent of the Style End Grassing Beds of Dr. Nicholson. (See Fig. 5, p. 261, and 'Proc. Geol. Assoc.,' Vol. ix, No. 7, Fig. 1.)

Near here a few sections of the Upper Old Red were seen. These beds were compared with the overlying quartz-conglomerates of the Roman Fell Beds (which represent part of the Mountain Limestone of the district west of Appleby). Some of the party made the ascent of Roman Fell, but the unfavourable weather deprived them of the fine prospect that eminence usually commands.

Before leaving the slopes of Roman Fell the Director briefly described the chief glacial features of interest, especially the distribution of the Brockram, and the Dufton "granite" in the drift. Attention was also directed to several small coums, and to the remarkably large glacial furrows that traverse the lowlands of Edenside at this point. Some observations were also made upon the sediment left on the melting of the Ice-sheet.

Rain fell at intervals throughout the day, but the fine scenery and the interesting geological features, combined with the President's inexhaustible fund of good humour, helped to keep matters pleasant for all.

Friday, August 9th. Long Marton, Knock, and Dufton Pike.—After a walk across the moors from Long Marton, Knock was reached about 10 a.m., and the party at once began to study the sections exposed in Swindale Beck. In the lower part the beds seen were of St. Bees Sandstone, as in Hetton Beck; but at the point where the Outer Pennine Fault crosses the base of the Coniston Flags (= Wenlock Shale) are brought up to the day. From these beds several members of the party obtained specimens of *Monograptus priodon* and *M. colonus*. Scrambling through the wet herbage by the side of the beck, the geologists next came upon the highest beds of the "Pale Slates" (Tarannon), down into which the Coniston Flags everywhere graduate. These beds consist of hard porcellaneous argillites of a pale sea-green colour, and are regarded by the Director as an "abysmal" deposit. Some time was spent in examining this rock, and in studying an interesting exposure of minette dyke, which here traverses the Pale Slates. The dyke was seen to graduate at its sides into the rock adjoining. Following up Rundale Beck the party next examined the Graptolitic Mudstone, down into which the "Pale Slates" are seen to graduate. These Mudstones overlie the Bala beds unconformably, and form, with their basal conglomerates, the natural base of the Silurian

Series. But from these Mudstones the party obtained *Climacograptus normalis, Diplograptus pristis, D. palmeus, D. tamariscus, Rastrites peregrinus, Monograptus sedgwickii.* Many other "characteristic Lower Silurian" graptolites have been obtained from these beds.

The party next examined some curious mounds at Cosca, which the Director regarded as representing older glacial sediment that had been pushed out of the valleys above by the advance of the small glaciers dating from the minor period of glaciation. This view was vigorously attacked by one gentleman present. Next, the felsite quarry near Hallsteads was examined, and then the quarry whence the Dufton "Granite" (mica-quartz-felsite) is obtained. This well-marked rock is of interest in many ways, but especially on account of its transportal in the drift to elevations higher by a thousand feet or more than the parent mass. At the quarry the Director made some general observations upon the geological structure of the country around. Afterwards a move was made in the direction of Dufton Pike, which (and also Knock Pike) consists of a thick pile of rhyolitic tuffs, immediately underlying the Coniston Limestone of Swindale Beck and Pusgill. The south face of Dufton Pike represents the floor on which the soft Coniston Limestone of Pusgill once lay, but has been denuded by weathering. Avoiding the climb to the summit of the Pike, the party wended their way round by its north side, which owes its present steep face to the fact that the Middle Pennine Fault has there brought up against the durable tuffs a less-durable mass of Skidda Slates, which are well seen on Brownber. Here the Director pointed out long glacial ruts, which traverse the hill from end to end. At the south end of Brownber some observations upon the origin of inosculating valleys were made, and then the evidences for the Middle Pennine Fault were described. The Inner Pennine Fault was also well seen from this point. Here some of the party elected to go on to Dufton Fell to examine the Dufton Mines, while the remainder decided to examine the junction of the Dufton Pike tuffs with the overlying Coniston Limestone, and to collect fossils from these beds in Pusgill. But the weather proved unfavourable, except for the study of pluvial denudation, and the party were glad to forgather at the inn at Dufton. After getting some tea, the excursionists had a pleasant walk past Dufton Gill and Troutbeck to Long Marton Station, thence by train back to Carlisle.

Saturday, August 10th. Nunnery Walks, Combs Wood, and Cote-hill.—The last day of the 1889 Long Excursion was devoted to visiting Nunnery Walks and the district adjoining. For the first time during the Excursion the weather was favourable, and, consequently, the walk was enjoyed by all the members of the party. The route through "Nunnery" lay alongside Dale Beck, which is here very finely wooded. The river gorge (or gill) itself consists of a series of deep river-fonts, which, through prolonged erosion, have eventually been connected with one another. As the fonts enlarge they all tend to become flask-shaped, through the progressive widening and deepening of their lower parts, while their earlier formed parts remain unworn. From this cause the connection between two adjoining fonts has occasionally been effected at some depth below the level at which they were initiated. In this way an arch or even a natural bridge has here and there been left. One of these natural bridges will long be remembered by the party as the scene of a somewhat exciting incident on the occasion of their visit.

These natural arches and bridges owe much of their present form to the low rate of horizontal denudation of this, the hardest part of the Penrith Sandstone, under the action of simple weathering, as compared with the high rate of the vertical denudation effected by the rotatory action of stones upon the river-bed during floods. The ratio of vertical to horizontal erosion here must be at least as high as ten to one.

At the junction of Dale Beck with the Eden, the Director made some observations upon the origin of the chief features of interest in connection with the Penrith Sandstone—its prevalent westerly false-bedding, indicating a derivation of the material from the east, the cause of the absence of mica—the origin of the secondary quartz crystallized around its sandgrains and other matters, already referred to in his paper (p. 258).

Leaving the Gill, the party next rambled through Combs Wood, on the north bank of the Eden, where the combination of woodland, rock, and river scenery was much admired. At the north-west end of the wood the Armathwaite Dyke is well-exposed in the bay above Armathwaite Mill, on the Eden. This Tertiary (augite-andesite) dyke extends from Cleveland, in North Yorkshire, through Cumberland, past Dalston Hall (where it was discovered in 1874 by the present writer), to at least as far as near Annan, in Dumfries.

The route now lay through the beautiful village of Armathwaite to the Knothill gypsum-quarries, near Cote Hill. Here the

Director gave a brief summary of the history of the rock,* and then a pleasant ramble through the fir woods of High Stand Plantation brought the party to Englethwaite, where Mr. and Mrs. Thomlinson kindly welcomed the party to a rest and some tea and light refreshments. Then the party dispersed, and the Long Excursion of 1889 came to an end.

Sunday.—A large number of the Members left for London, the Lake Country, and other places on Saturday evening, about a dozen remaining in Carlisle on Sunday (11th). Of these, most visited Silloth in the afternoon, in spite of the weather, which promised to be showery, at least. The journey was across a country, the surface of which consists of ill-marked ridges of Glacial Drift alternating with broad alluvial flats. Most of the way between Carlisle and Drumburgh the railway is on the side of the canal between Carlisle and the ill-fated Port Carlisle. Near the eastern border of Burgh Marsh, and north of the railway, is a monument marking the spot at which King Edward I. breathed his last, and south of Drumburgh a low-lying peat-moss of considerable size is noticeable. At Abbey Town the railway passes near the Abbey Church, but the aspect of "Holm Culkam's lofty nave"—known to readers of the "Lay of the Last Minstrel" as the burial place of the brave Musgrave—is not imposing to those who know the abbey churches of districts beyond the influences of the Border Wars. Crossing the broad alluvial flat between Abbey Town and Silloth, the slightly raised beach on which Silloth stands was reached. In spite of heavy showers, which caused a halt of about half-an-hour at the Railway Station, the journey had been a pleasant one, as the Lake Country mountains, which show to special advantage from the low-lying ground near the Solway, stood forth with singular clearness, and before the party returned to Carlisle, Criffel, and the hills of Dumfriesshire and Galloway appeared with equal distinctness and beauty. From the Solway near Bowness or Annan, the sovereignty of Skiddaw among the mountains, which is by no means always conspicuous from other points of view, is unquestionable. Its form, too, appears to be much finer when seen from the north, than from the south-east or west. From Bowness or Annan it is a lofty peak; from Workington or Whitehaven it is more like a huge haystack. From the south, at Keswick, its double front and superior size are manifest, but he

* See 'Proc. Geol. Assoc.,' Vol. x, p. 436.

who wishes to see Skiddaw at its very best must view it from a point nearly due north on the shores of the Solway.

Monday, August 12th.—The eight or nine remaining Members left Carlisle by an early train for Naworth. Between Head's Nook and Naworth Stations the route was through the Esker tract, the deep cutting known as the Couran Cut being excavated in Esker sand and gravel. Isolated Eskers were seen in Naworth Park and at many spots higher up the valley of the Irthing, especially near Gilsland Station. On the other hand, between Carlisle and Head's Nook the contours of the ground are very flattened and regular. The border castle of Naworth was visited and a beautiful view of the surrounding country obtained from the top of one of the towers. Of the internal arrangements it need only be said here that, though a place of residence at the present day, its general character as a border castle has been preserved, and visitors can see the bedroom, library, and other apartments of "Belted Will Howard" unaltered and presenting the aspect they had when the Scottish Borderers had to be ever on the watch —

> "Lest Scroop, or Howard, or Percy's powers
> Threaten Branksome's lordly towers
> From Warkworth, or Naworth, or merry Carlisle."

Leaving the castle, the party crossed the park and emerged from it close to the bridge over the Irthing between Naworth Castle and Lanercost Priory. After refreshment at the inn close by, they noted the appearance of Carboniferous Sandstone in the stream on the western side of the bridge, and were informed by the Director that they were then on the eastern side of the line of fault bounding the Permian-Triassic rocks, though St. Bees Sandstone was visible in the river two or three hundred yards below the spot at which they were then standing.

Lanercost Priory was seen to stand on an upper alluvial terrace on the northern side of the valley, in a position at once warm, sheltered from the north winds, and above the reach of floods. It may be added that the great majority of English abbeys and priories are to be found in similar situations. In the time of King Henry I. this priory suffered much at the hands of the Scots on one occasion, while on two others the monarch himself was the prior's guest. His last visit was in the year 1306, and he stayed there till Easter, 1307. Thence he went to Carlisle, and from Carlisle to Burgh Marsh—there to die. Part of the priory church is in use at the present day and part is in ruin.

From Lanercost Priory the party proceeded in a north-easterly direction towards Gilsland. The hamlet known as Banks being reached, the route was along the straight road, thence to the Roman Camp known as Amboglanna or Birdoswald. Between those places the road is on the site of the Roman Wall, the fosse on the northern side of the structure being almost continuously visible in the fields on the left side, and often retaining a considerable proportion of its original depth. South of the road the series of earthworks known as the Vallum was often very well marked, especially near the farm known as High House. Close to, but west of Amboglanna, there is a considerable fragment of the Roman Wall, and the camp itself presents many interesting features, the details of the gateways being very clearly shown.

From Amboglanna the path across the fields in the direction of Gilsland Spa was taken. On arrival at the Spa the water, which is strongly impregnated with sulphuretted hydrogen, was smelt, if not tasted. Fine sections in the Carboniferous rocks of the neighbourhood are visible in the high banks of the Irthing, near the Spa, and elsewhere. They consist of sandstones and shales; that above the Spa showing a large quantity of dark shale with bands of sandstone. The "Poppingstone," a short distance above the Spa, is a block of rock lying close to the river bed, and famous as the stone on which Sir Walter Scott is said to have proposed to his future bride. Mr. Jenkinson, in his Guide to this part of Cumberland, remarks that this stone is now only half its original size, as people are constantly chipping off bits to take away with them, believing that when placed under the pillows of unmarried women they cause the sleepers to dream of their future partners; but as the Director was not then aware of the existence of this belief he did not mention it to the unmarried ladies of the party. Consequently the stone has suffered no further reduction at the hands of any Members of the Association. A hurried walk to the railway-station enabled the party to catch the train for Carlisle.

Tuesday, August 13th.—Only four Members appeared at the Carlisle Railway Station on Tuesday morning with the intention of seeing the Permian-Triassic rocks between the Nith and the Lochar Water, and of visiting the remains of the famous Castle of Caerlaverock. Between Carlisle and Annan no sections of any kind appeared, though signs of the presence of Glacial Drift were occasionally visible in the cuttings. However, a little St. Bees Sandstone was visible in the Annan Water close to the railway-bridge, and around

Cummertrees and Ruthwell were many Esker ridges. The peaty flat drained by the Lochar Water was then crossed, and the party alighted at Dumfries, and drove in an open carriage towards Caerlaverock. About a mile north of the castle, at the spot where "Woodend" appears on the one-inch ordnance map, is a fine quarry, in which the character of the Red Sandstone lying between the Nith and the Lochar Water was extremely well displayed. It was at once evident that it was in every respect precisely similar to the Penrith Sandstone of the Eden Valley, and the gigantic scale of the false-bedding was even better shown on this side of the Solway than it had been in any of the Cumberland sections we were able to visit.

Caerlaverock Castle is situated on low ground, and is surrounded by a moat. Its plan is triangular in shape, and on entering it was seen that a mansion of the seventeenth century was enclosed by the grim outer walls of the castle. Before starting for the return journey to Dumfries the Director read aloud "The Murder of Caerlaverock" from 'Scott's Border Minstrelsy.'

The party drove back to Dumfries by the road which keeps nearest to the Nith. South of Glencaple the Brockram or breccia, which is interbedded with the Red Sandstone, was very well shown close to the road. On arrival at Dumfries they visited the Burns Mausoleum in the burial ground of the Church of St. Michael, and walked through the town to the railway-station.

The Long Excursion of 1889, though marked by an unusual amount of rain, appears to have been much enjoyed by those who took part in it, and will doubtless long remain a pleasant though not sunny memory. Indeed, though the daily showers generally prevented the day's programme from being perfectly carried out, yet nothing of real importance was omitted on account of the weather but the proposed walk down the river Line from Brackenhill Tower to Cliff Bridge. After dinner on Friday, the 9th, Mr. Parker proposed a vote of thanks to the Directors. The President, in acknowledging it, remarked that the gratitude of the Members was much more largely due to Mr. Goodchild than to himself, inasmuch as Mr. Goodchild had very lately been suffering from an illness which made his attendance at the Excursion a matter involving a most serious risk. It is most gratifying to be able to add that, since the Excursion, Mr. Goodchild has stated that his health has been improved, not injured, by his trip to Edenside.

ORDINARY MEETING.

FRIDAY, NOVEMBER 1ST, 1889.

T. V. HOLMES, Esq., F.G.S., President, in the chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—G. W. Bryne and Rev. G. Scudamore.

A letter was read from Mr. W. H. Corbould, of the Flora Bell Silver Mining Company, Port Darwin, North Australia, and the accompanying specimens were exhibited. Mr. Corbould writes:—"With this mail I am sending you a piece of kaolin containing chloride of silver, from Broken Hill Co. Barrier Ranges, New South Wales, and a piece of ore containing native silver, from Flora Bell. On pieces of ore from this mine I noticed crystals of native silver a few years ago. I experimented with electro-plating solutions—in one of the experiments I dissolved chloride of silver in ammonia, added water, and passed a current of electricity from a bichromate battery through the solution. After leaving it for an hour I thought the surface of the solution looked peculiar. I examined the solution under a glass, and noticed crystals of metallic silver. The cathode was also covered with crystals. I used a silver cathode and anode. The crystals may have been formed before by the same process, but if so I have not read of it. The Flora Bell lode is a fissure, having a direction of N.W. and S.E., the strata that the lode is in being slate. I have not been able to find any fossils. The slate extends on both sides of the lode for a great distance. East and west of the slate is the granite. I will send you a collection of ores and country formations shortly."

A communication was also read from Mr. C. F. Fox on a specimen of *Exogyra digitata*, Sow., from Cerne Abbas, which was exhibited.

The following paper was then read:—'Metal Mining,' by UPFIELD GREEN, F.G.S.

ORDINARY MEETING.

FRIDAY, DECEMBER 6TH, 1889.

F. W. RUDLER, Esq., F.G.S., M.A.I., Vice-President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

On the motion of Dr. Henry Woodward, F.R.S., seconded by Dr. Henry Hicks, F.R.S., it was resolved that the Secretary be requested to convey to the President and Mrs. Holmes, on behalf of the Members, their deep sympathy and condolence with them in their late sad bereavement.

The meeting was then resolved into a conversazione, at which the following objects, among others, were exhibited:—

By W. J. LEWIS ABBOTT, F.G.S.—Eocene Mollusca from the Paris Basin.

By F. W. AMSDEN—Photographs of Switzerland.

By W. J. ATKINSON—Igneous Rocks from Arthur's Seat, with micro-sections.

By Professor J. F. BLAKE, F.G.S., who also gave a demonstration with the lantern of slides of geological interest, including those brought by other Members—Petrological Microscope and a series of sections of Crystals, showing optical pictures, rings, etc.

By G. W. BUTLER—Photographs taken during the Italian Excursion.

By M. F. A. CANNING—Specimens of very rich Gold Quartz, etc., from Two Brothers' Reef, near Southern Cross, and Golden Valley, Yilgarn, Western Australia; and samples of Stream Tin from the Green Bushes Tin Field, Blackwood district, Western Australia.

By C. CHRISTOPHERSON—An oil-painting of a Buttermere Parson on Buttermere slate.

By G. A. J. COLE, F.G.S., and J. W. GREGORY, F.G.S.—Specimens of the Variolite of Mont Genèvre, and of some rocks associated with it in the field.

By J. T. DAY—Eocene Mollusca from the Paris Basin.

By G. E. EAST, jun.—Eocene Mollusca from Claiborne, Alabama, U.S.

By A. S. Foord—Lava from Teneriffe, collected by J. Tyhurst, Esq., November, 1889.

By James Fox—A collection of Chalk Fossils.

By L. W. Fulcher, B.Sc.—A series of Rock Specimens, collected on the Italian Excursion.

By J. R. Gregory—Cast of original mass and two specimens of Meteoric Iron, from Thunda, Windorah, Queensland, showing exterior, polished and etched surfaces.

By J. D. Hardy—A new and simple micrographic apparatus.

By S. Henson—Gold nuggets from Johannesberg, a new mineral, Eudidymite; Argyrodite containing the rare metal, Germanium; Vanadinite; Thorite; Castor crystal; twin Calcite, etc., etc.

By C. Holme, F.L.S.—Quartz Crystals, from the Koshiu district, Japan, with enclosures of actinolite, water, etc.; and a series of specimens showing the process of working into spheres, etc.

By J. Hopkinson, F.L.S., F.G.S.—Maps and plates to G. P. Scrope's 'Volcanic Formations of Central France,' the author's copy with his corrections.

By S. H. Needham, F.G.S., F.R.G.S.—Crystals of the precious metals, gems, Fontainebleau sandstone, and other minerals; Mocha-stones, agates; Devonian corals; Oolitic and other fossils; micro-slides of minerals, sponge-spicules, Polyzoa and Foraminifera; and recent Polyzoa from South Australia.

By F. W. Rudler, F.G.S.—A series of Volcanic Products, chiefly from Vesuvius, with large reproductions of the views in Hamilton's 'Campi Phlegræi.'

By G. Smith, who also most kindly provided lamps for the microscopes brought by other Members—Microscopes and appliances relating to geology.

By Rev. F. A. Walker, D.D.—Specimens of lava from different localities in Iceland, collected by himself.

By William White, with the lantern, a series of photographs from Mr. Nasmyth's models of the chief volcanic features of the moon, some of which were kindly lent by Messrs. Negretti and Zambra.

ORDINARY MEETING.

FRIDAY, JANUARY 3RD, 1890.

T. V. HOLMES, Esq., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the gift of nineteen photographs of volcanic outbursts by Dr. Lavis, and that of a complete limelight oxy-hydrogen lantern, with lenses, microscope, and gasholders, from J. E. H. Peyton, F.G.S., and the thanks of the Association were accorded to the various donors

The following were elected Members of the Association :—J. Baker; Miss C. Birley; W. H. Brown; Montagu Browne, F.Z.S.; G. Chandler; W. H. Corbould; G. A. Freeman, B.Sc., F.G.S.; R. McAllan; A. C. Seward, M.A., F.G.S.; and Miss M. T. Webb, B.Sc.

Mr. Upfield Green, F.G.S., and Dr. J. Morison were elected auditors.

The following papers were then read :—

'On the Fossil Fishes of the English Lower Oolites,' by A. SMITH WOODWARD, F.G.S.

'A short account of the Excursion to the Volcanic Regions of Southern Italy,' by Dr. H. J. JOHNSTON LAVIS, F.G.S.

Specimens from the collection of T. Jesson, F.G.S., were exhibited by Mr. A. SMITH WOODWARD in illustration of his paper; and photographs of the volcanic regions of Italy were exhibited by Dr. LAVIS and Mr. G. W. BUTLER, F.G.S., in illustration of the paper by the former.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 7TH, 1890.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

Messrs. W. J. Lewis Abbott and Williams were appointed scrutineers of the ballot.

The following Report of the Council for the year 1889 was then read:—

The numerical strength of the Association on the 31st of December last was as follows:—

Honorary Members	16
Ordinary Members:—	
a Life-Members (Compounded)	134
b Old County Members (5s. Annual Subscription) ...	12
c Other Members (10s. Annual Subscription) ...	356
Total	518

During the year 22 new Members were elected. The Council regret that the Association lost three Members by death—J. D. Stokes, F. Gotto, and G. T. Millar.

The financial position of the Association is in a better condition than a cursory inspection of the statement of receipts and expenditure would seem to convey. In the previous report it was stated that the expenditure in the year 1888 had been unusually heavy, and the same may be said of 1889, in which the expenditure was much greater than in the previous year, exceeding the year's receipts available for income by £70. It is satisfactory, however, to be able to state that the whole amount received for life-compositions in 1888 and 1889, namely 50 guineas, has been invested, and that the present value of the invested property of the Association more than covers the composition-fees of the existing life-members. The unusually heavy expenditure was almost entirely due to the publication of nearly double the average annual number of pages in the 'Proceedings,' thus bringing them up to date. For Balance Sheet see next page.

During the year No. 9 of Vol. x, which belonged to 1888, and five numbers of Vol. xi, were issued to the Members, making in

GEOLOGISTS' ASSOCIATION.

Income and Expenditure for the Year ending 31st December, 1889.

Dr.

	£	s.	d.
To Balance from 1888...	90	17	7
„ Life Compositions	26	5	0
„ Admission Fees	13	0	0
„ Annual Subscriptions	177	15	0
„ Dividends on £744 8s. 6d. Nottingham Corporation Three per cent. Stock	21	15	6
„ Sale of Publications	10	2	1
„ Advertisements	1	12	6
„ Balance due to Treasurer	6	0	0
	£347	7	8

Cr.

	£	s.	d.
By Printing 'Proceedings'	160	0	5
„ „ Monthly Circulars	15	16	0
„ Illustrating 'Proceedings' and Circulars ...	12	7	0
„ Miscellaneous Printing...	18	6	4
„ Postages	49	1	3
„ Addressing	9	9	0
„ Library	8	16	6
„ Attendance, Gas, &c., at Evening Meetings	12	16	0
„ Fire Insurance for 1890	1	17	6
„ Purchase of Set of 'Proceedings,' &c. ...	4	0	0
„ Indexing Minutes of Council	1	10	0
„ Stationery and Miscellaneous Expenses ...	0	17	8
	£294	17	8
„ Purchase of £53 4s. 6d. Nottingham Corporation Three per cent. Stock	52	8	6
„ Broker's Commission	0	1	6
	£347	7	8

We have this day examined the Accounts of the Treasurer of the Geologists' Association, and we find the above Statement to be correct.

21st January, 1890.

(Signed) UPFIELD GREEN, JOHN MORISON, M.D., } Auditors.

all 510 pages, with two plates and sixty-five other illustrations, four of which are large folding pages. In short, as much was printed as in any two years between 1879 and 1884.

The Association is indebted to Mr. W. H. Hudleston, F.R.S., and to Mr. A. Smith Woodward, F.G.S., for the plates and other illustrations to their respective papers, and to Mr. J. G. Goodchild, F.G.S., for the maps illustrating the report of the Long Excursion.

The General Index to the first decade is in progress, and it is hoped may be issued before many months.

The Record of the Excursions has, owing to several causes, been delayed; but your President has resolved that its production shall be one of the events marking his term of office, and an accomplished fact before long.

The Library continues to be increased by the addition of many valuable works received both as donations and in exchange for the 'Proceedings.'

The new position of the book-case is certainly an improvement, and advantageous both to those wishing to consult the books and to the assistant librarian. Your thanks are again due to Mr. E. Litchfield, for continuing so ably and regularly to assist in the work of the Library.

The valuable gift of a lime-light lantern, complete with microscope and accessories, calls for your special acknowledgment to its generous donor, Mr. J. E. H. Peyton. This instrument will undoubtedly prove of the greatest utility in facilitating the illustration of papers.

The following is a list of the Papers read at the evening meetings:—

'On some Bagshot Pebble-Beds and Pebble-Gravel,' by Horace W. Monckton, F.G.S., and R. S. Herries, M.A., F.G.S.

'On the Palæontology of Sturgeons,' by A. Smith Woodward, F.G.S.

'Experimental Geology,' formed the theme of the President's address.

'The Geological History of Iron Ores,' by Wilfrid H. Hudleston, F.R.S., Sec.G.S.

'A Visit to the Volcanoes of Italy,' by Professor J. F. Blake, M.A., F.G.S.

'Note on a Chelonian Humerus from the Middle Eocene of Bracklesham,' by R. Lydekker, B.A. F.G.S.

'On Rocks from the Saas-Thal and Geneva,' by Captain Marshall Hall, F.G.S., F.C.S.

'Geology before 1800,' by E. Litchfield.

'Notes on the Artificial Unmaking of Flints,' by T. Hay Wilson.

'The Geology of Upton and Chilton in Berks,' by A. J. Jukes-Browne, B.A., F.G.S.

'The Geology of North-West Cumberland,' by T. V. Holmes, F.G.S.

'The Geology of the Eden Valley District,' by J. G. Goodchild, F.G.S.

'On the Estuary of the Thames and its Alluvium,' by Flaxman C. J. Spurrell, F.G.S.

'On Metal Mining,' by Upfield Green, F.G.S.

A conversazione was held on December 6th.

Various objects of interest have been exhibited at the evening meetings, but the practice is one which your Council would gladly see more often and more extensively carried out.

Subjoined is a list of the Museums visited during 1889 :—

British Museum (Natural History), Cromwell Road, on March 16th, when Mr. W. Carruthers, F.R.S., the Keeper of the Botanical Department, conducted the party through his Gallery, and gave an Exposition of the Fossil Fungi, Lichens, and Mosses.

Royal College of Surgeons, Lincoln's Inn Fields, on April 6th, when Prof. Charles Stewart, F.L.S., Curator of the Museum, gave a Demonstration on some of the objects there exhibited.

Dr. John Evans, F.R.S., showed the Members his magnificent Collection of Flint Implements, on the occasion of their visit to Nash Mills, on the Boxmoor Excursion, May 18th.

Mr. Harrison, on the Ightham Excursion, June 1st, exhibited to those present his Collection of Flint Implements from that neighbourhood.

Ipswich Museum, on June 10th, over which Dr. J. E. Taylor, the Curator, conducted the party that formed the Whitsuntide Excursion to the Crag District.

Mr. A. M. Bell, on the Excursion to Limpsfield, July 13th, showed the Members present his Collection of Flint Implements from the gravel-pits there.

The following is a list of the Excursions made during the past year, detailed reports of which will be found in the number of the 'Proceedings' for November, 1889 :—

To Lyme Regis, on April 19th and 20th, under the direction of H. B. Woodward, F.G.S.

To Weymouth, on Easter Monday and Tuesday, April 22nd and 23rd, under the direction of W. H. Hudleston, M.A., F.R.S.

To Boxmoor and Nash Mills, on May 18th, in association with the Hertfordshire Natural History Society, under the direction of J. Hopkinson, F.L.S., F.G.S., and John Morison, M.D., F.G.S.

To Brentwood, on May 25th, in association with the Essex Field Club, under the direction of H. W. Monckton, F.G.S., and H. B. Woodward, F.G.S.

To Ightham (Kent), on June 1st, under the direction of Prof. J. Prestwich, D.C.L., F.R.S., and W. Topley, F.R.S.

To the Crag District, at Whitsuntide, June 8th to 11th, under the direction of W. Whitaker, F.R.S., F.G.S., and Dr. J. E. Taylor, F.L.S., F.G.S.

To Higham (Kent), on June 22nd, under the direction of F. C. J. Spurrell, F.G.S.

To Dunstable, for Totternhoe and Ivinghoe, on June 29th, in association with the Hertfordshire Natural History Society, under the direction of J. Hopkinson, F.L.S., F.G.S.

To Limpsfield (Surrey), on July 13th, under the direction of Prof. J. Prestwich, D.C.L., F.R.S., and W. Topley, F.R.S.

To Chilton, on July 20th, under the direction of W. Whitaker, F.R.S., F.G.S.

To North-West Cumberland and the Eden Valley District, from August 5th to 10th, under the direction of The President and J. G. Goodchild, F.G.S., etc.

The thanks of the Association are especially due to the following for assistance and hospitality at the Excursions: Sir Henry Peek, Mr. Cuthbert E. Peek, and Mr. C. Grover; Dr. John Evans, F.R.S.; Mr. Thomas Johnson, Broomsleigh, Seal, near Sevenoaks; Mr. B. Harrison, Ightham; Mr. A. M. Bell, Manor House, Limpsfield; Mr. J. Thomlinson, Englethwaite, near Carlisle.

Your thanks are also due to the Council of University College for the use of their rooms in which to hold our meetings and for according permission to hold the conversazione in the Library.

Although not an Excursion of the Association, the visit of the party of geologists to the volcanic regions of Southern Italy, originating in a proposal by Dr. Lavis, calls for mention, inasmuch as this Association took the initiative in its organization and its Members formed the majority of the party. Of its success those who attended it can speak, whilst the great kindness and assistance, to say nothing of the hospitality, they received on all hands during the weeks spent in that lovely and most interesting neighbourhood, will cause that expedition to be a never-forgotten experience and a pleasurable recollection.*

* Thanks are specially due in this connection to Dr. H. J. Johnston Lavis; Prof. O. Silvestri, of Catania; Prof. Bassani, of Naples; Sig. Gaetano Platania, Mem. Geol. Assoc.; Sig. Giovanni Platania; Prof. A. Sacchi, of Naples; Prof. Michele Ruggiero; Prof. G. Strüver; Prof. J. R. Meli, of Rome; Prof. P. Zezi, of Rome; Sig. T. Tittoni; The Syndic of

Dr. Foulerton, finding that his absence from England will extend beyond the period when the Excursions begin, has tendered his resignation, which your Council have, therefore, been reluctantly compelled to accept.

Dr. Foulerton has held the office of Secretary since February, 1877, and on him has devolved the task of organizing and arranging for thirteen years those Excursions which form one of the leading features of this Association; whilst for the first ten years he was charged with the ordinary business in addition.

Your Council has not as yet, owing to the short notice they received of his intention, been able to nominate a successor.

Mr. B. B. Woodward, who has been joint Secretary with Dr. Foulerton since April, 1886, also resigns his office this year.

Your Council have great pleasure in nominating as his successor Mr. C. Davies Sherborn, F.G.S., whose careful and reliable work, as evinced in his 'Bibliography of the Foraminifera' and in his share of the 'Catalogue of British Fossil Vertebrata,' is a guarantee that the affairs of the Association will assuredly not suffer in his hands.

Your Council have much pleasure in recommending for election as Honorary Member of the Association, Alexander Henry Green, M.A., F.R.S., F.G.S., etc., Professor of Geology in the University of Oxford. Prof. Green has rendered eminent service to geology, not only whilst attached to the staff of the Geological Survey, when many most valuable Memoirs were prepared by him, but also, as Professor of Geology at the Yorkshire College of Science, Leeds, in promoting the study of the science, both by his teaching and by his published works.

On the motion of Mr. J. W. Gregory, F.G.S., seconded by Mr. W. J. Atkinson, F.G.S., the Report was adopted as the Annual Report of the Association.

Naples; Prof. Spatuzzi, of Naples; Sig. Seguenza; Marquis di Favara, of Biancavilla, Sicily; Dr. A. Sambon, of Naples; Mr. L. Sambon, Dr. Eisig, Vice-Director, Zoological Station, Naples; Sig. Dini; Dr. Cerio, of Capri; C. W. L. Ostermoor, Esq., of Capri; Cav. Amore of Roccamonsina; Dom Oderisio Piscicelli, Prior of Monte Cassino; Prof. Portis; Cav. Ing. Zezi, Secretary Comitato Geologico; Sig. Clerici, of Rome; Sig. De Marchi; Count Guiseppe Savorgnan di Brazza; and Prof. Lanciani, of Rome.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year :—

PRESIDENT:

T. V. Holmes, F.G.S.

VICE-PRESIDENTS:

Rev. Prof. T. G. Bonney, LL.D., F.R.S., F.G.S.
W. H. Hudleston, M.A., F.R.S.
F. W. Rudler, F.G.S.
W. Topley, F.R.S., F.G.S.

TREASURER:

John Hopkinson, F.L.S., F.G.S.

SECRETARY:

C. Davies Sherborn, F.G.S.

EDITOR:

Prof. G. S. Boulger, F.L.S., F.G.S.

LIBRARIAN:

John Bradford, F.G.S.

COUNCIL:

Prof. J. F. Blake, M.A., F.G.S.
Rev. Prof. T. G. Bonney, F.R.S.
Prof. G. S. Boulger, F.L.S., F.G.S.
John Bradford, F.G.S.
Rev. E. S. Dewick, M.A., F.G.S.
W. B. Gibbs, F.R.A.S.
Upfield Green, F.G.S.
T. V. Holmes, F.G.S.
John Hopkinson, F.L.S., F.G.S.
W. H. Hudleston, M.A., F.R.S.
Major-Gen. C. A. McMahon, F.G.S.
Prof. R. Meldola, F.R.S.
H. W. Monckton, F.G.S.
S. H. Needham, F.G.S.
E. T. Newton, F.G.S.
Miss C. A. Raisin, B.Sc.
F. W. Rudler, F.G.S.
C. Davies Sherborn, F.G.S.
J. Slade, F.G.S.
W. Topley, F.R.S., F.G.S.
B. B. Woodward, F.G.S.

TRUSTEES:

Arthur Bott, F.G.S.
Rev. Prof. T. Wiltshire, M.A., F.G.S.
Henry Woodward, LL.D., F.R.S., F.G.S.

The President announced that Dr. Foulerton had felt obliged to resign the office of Excursion Secretary, but that his resignation had been received too late for his name to have been withdrawn from the ballot-paper, and that the office was at present vacant.

On the motion of Mr. T. Leighton, F.G.S., seconded by Mr. J. P. Smart, the thanks of the Association were unanimously voted

to the Vice-President and Members of Council retiring from office, to the retiring Secretaries, to the Auditors and to the Scrutineers.

The President then delivered his Address, entitled 'Notes on the Nature of the Geological Record.'

On the motion of Mr. W. H. Monckton, F.G.S., seconded by Mr. H. B. Woodward, F.G.S., it was unanimously resolved that the President's Address be printed *in extenso*.

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, FEBRUARY 7TH, 1890.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the Library since the previous Ordinary Meeting were announced, and the thanks of the Association accorded to the respective donors.

There being no paper, the proceedings then terminated.

ORDINARY MEETING.

FRIDAY, 7TH MARCH, 1890.

T. V. HOLMES, Esq., F.G.S., President, in the Chair.

The donations to the library were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association:—Miss Emily Aston, B.Sc., and John Winder Holmes.

A letter was read from Prof. A. H. Green, F.R.S., F.G.S., thanking the Association for electing him an Honorary Member.

The following papers were then read:—

'On the Pleistocene (non-marine) Mollusca of the London District,' by B. B. Woodward, F.G.S.

'Notes on some Pleistocene Sections in and near London,' by W. J. Lewis Abbott, F.G.S.

'Note on a curious appearance produced by the natural bisection of some spherical concretions in a Yoredale Stone Quarry near Leek,' by Wheelton Hind, M.D.

Specimens in illustration of their respective papers were exhibited by the authors.

ORDINARY MEETING.

FRIDAY, MAY 2ND, 1890.

T. V. HOLMES, F.G.S., President, in the Chair.

The donations to the library were announced, and the thanks of the Association accorded to the various donors.

The following papers were then read:—

'On the manufacture of Serpentine in Nature's laboratory,' by Major-General C. A. McMahon, F.G.S.

'On a new species of *Capulus*,' by Prof. G. S. Boulger, F.G.S.

'On the occurrence of Amberite (Retinite), or fossil gum, in a seam of coal at Kawa Kawa Colliery, Bay of Islands, New Zealand,' by T. P. Moody, M.E.

ORDINARY MEETING.

FRIDAY, JUNE 6TH, 1890.

T. V. HOLMES, Esq., President, in the Chair.

The donations to the library were announced, and the thanks of the Association accorded to the various donors.

The following gentleman was elected a Member of the Association :—H. L. Sargent.

The following papers were then read :—

'On the pebbly and sandy beds overlying the Woolwich and Reading series, on and near the Addington Hills,' by H. M. Klaassen, F.G.S.

'On the Auriferous Series of Nova Scotia,' by G. F. Monckton.

'An instance of recent erosion near Stirling,' by H. W. Monckton, F.G.S.

There were exhibited :—A series of mineral specimens from Port Darwin, by W. H. Corbould ; a series of fossils collected in the Crayford and Erith Excursions, by Thomas Leighton.

ORDINARY MEETING.

FRIDAY, JULY 4TH, 1890.

T. V. HOLMES, Esq., President, in the Chair.

The donations to the library were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association :—F. H. Smith, H. S. Streatfield, H. L. Morgan, Miss A. G. Gibbon.

The following papers were then read :—

'Notes on the Geology of the Long Excursion to the Mendip Hills,' by H. B. Woodward, F.G.S.

An extract from a paper by Prof. Lloyd Morgan on the Geology of the Mendip Hills.

There was exhibited :—A "Bread-Crust" Bomb ejected from Vulcano, March, 1890, by Dr. H. J. Johnston Lavis, who made some remarks on its peculiar structure.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

SATURDAY, 29TH MARCH, 1890.

DEMONSTRATION ON RECENT ECHINODERMATA, BY PROF. F. JEFFREY BELL.

The Members met in the Starfish Gallery of the Zoological Department, where Prof. Bell addressed them on the structure and habits of the Echinodermata, illustrating his remarks by a series of diagrams. It is impossible, in a brief space, to give any useful report of the lecture, which dealt in a full and lucid manner with sea-urchins, starfish, brittle-stars, crinoids, and holothurians.

EXCURSION TO NORTH STAFFORDSHIRE.

THURSDAY, APRIL 3RD, TO TUESDAY, APRIL 8TH, 1890.

Directors: WHEELTON HIND, M.D., B.S., F.R.C.S., JOHN WARD, F.G.S., T. WARDLE, F.G.S., F. BARKE, and A. SMITH WOODWARD, F.G.S.

(*Report by* DR. HIND.)

Members arrived at Stoke on Thursday afternoon and evening, and took up their quarters at the North Staffordshire Hotel. As only two, however, arrived in the afternoon, the visit to Beadwell Wood Quarry was omitted. It appeared that the name of the locality must have frightened many who thought that to spend Easter holiday in a manufacturing and coal and iron centre would be anything but pleasant, and the Director regrets that he did not advertise more strongly in the programme the beauties of the immediate neighbourhood; but he feels that those venturous spirits who bravely came to explore what they understood to be merely black country were rewarded with as fine rock, wood, and river scenery as any in the Midlands.

During the evening the Director, aided by maps, plans, and diagrams of sections, gave a short notice of the geological features of the country and the work to be done.

North Staffordshire is rich in geological features, and shows a fine series of beds from the Keuper to the Carboniferous Limestone

complete with highly interesting sections in three Drift beds at least. There are four coalfields: the Pottery Coalfield, the largest, covering 75 square miles; the Wetley and Stafferlong Coalfield, Goldsitch Moss Coalfield; and the Cheadle Coalfield, all which lie in basins.

The Pottery Coalfield—roughly triangular in shape, with its apex towards the north—is cut off on the west by the Red Rock fault, which brings up the Coal-Measures (and, further north, Yoredale beds) against Keuper beds of the Cheshire Plain. On the east the field is bounded by the outcrop of Millstone Grit in the form of hills locally called edges, but further south it is cut off by a fault and abuts against Keuper beds. To the south the Coal-Measures disappear below Permian and Triassic beds. North of the coalfield the country is composed of grits and Yoredale beds, which further east crop out, and the Carboniferous Limestone also comes to the surface. This part of the country is very hilly, and forms part of the main water-shed of England, streams on the west and north-west flowing west into the Mersey; those on the south, east, and south-east, into the Trent.

Most of the country is covered with drift.

There are perhaps more sections of Coal-Measures to be seen than in any other coalfield, owing to the demand for marl for manufacturing purposes, there being a large number of exposures in the Upper and Middle Coal-Measures. These subdivisions and their limits will be referred to lower down.

A section across North Staffordshire from east to west, starting at the Red Rock fault, would present a series of synclinals and anticlinals. The members of the Carboniferous series present are:—

1. *Upper Coal-Measures* 1,000 *feet.*

Includes all beds as far down as the *Spirorbis* Limestone, a marine band. These beds are chiefly marls, with one or two thin marly sandstones and some black-band ironstone and thin coals—the only one of importance being the Gutter or Fenton Low Coal, the highest notable coal in this coalfield.

2. *Middle Coal-Measures about* 1,400 *feet.*

Includes beds below the Spirorbis band, down to the Ash or Rowhurst coal, containing several ironstones and coals.

3. *Lower Coal-Measures about* 3,600 *feet.*

Including beds from the Ash coal to the Millstone Grit.

The Millstone Grit beds are subdivided into five beds of stone, separated by shales, and there is a thin coal generally lying on the top of each grit except the fifth. Of these beds the first and third grits are most developed, and form many of the features of the country. The second grit shows out soon after entering the county, while the fourth grit forms Axe Edge, the highest elevation in the county, 1,810 feet, and becomes lost about the Biddulph and Rudyard basin.

The Yoredale beds are estimated at 3,100 feet in thickness, and are subdivided as follows:—

Upper Beds.—Black shales, with Yoredale Grit of Farey.

Middle Group.—Close-grained quartz sandstones.

Lower Group.—Shales, with sandstones gradually passing into limestones.

These beds form the anticlinal ridges of Booley Mine, 1,200 feet, and Gun Hill (Sandstone), the latter an elevation of 1,000 feet; and again, further east, with an intervening synclinal valley, the ridge of Morredge.

The Carboniferous Limestone is estimated at 5,000 feet thick. The country occupied by it is characterized by dome-shaped hills. It terminates towards the south in the Weaver Hills, 1,156 feet, at the base of which it disappears below beds of Trias age.

April 4th.—A start was made at nine o'clock in a well-horsed break for Bucknall to inspect a section of Middle Drift sand and gravel. This sand is tolerably regularly bedded, but here and there are examples of current-bedding; small coal detritus forms well-marked black streaks in the bedding.

Amongst the stones are many quartzites, granites, greenstones, and trappean rocks, and a few Chalk flints. These flints are found in beds of the same character at Hardcastle and Madeley, the latter place about eight miles west. Here they are much more plentiful than at Bucknall.

Fifteen miles north-east at Birchwood Moor (Derbyshire) the Director had seen *Echinocorys ovatus* and Lias fossils in the drift.

The next item on the programme was a visit to a marl-pit at Joiners Square, Hanley. This pit is in the lower part of the Upper Coal-Measures, and a section of nearly 100 feet of marls is

to be seen, with stiff Boulder Clay as a cap, and two beds of coal, of which the Gutter Coal is probably one. This, and the neighbouring pit known as Messrs. Hampdens' Pit, are classic ground. Large numbers of large specimens of *Sigillaria*, several feet in circumference, have been exposed, all growing on one horizon. They were all erect or slightly inclined, but they soon weathered and fell to pieces. *Calamites* is common, and specimens were secured by several of the Members. Messrs. Hampden received the company, and showed plans of the workings.

Two more pits were visited at Fenton Low, one on the same horizon as the former. Over one the party were conducted by Messrs. Hewitt, who own the pit. This section (Fig. 1) is a

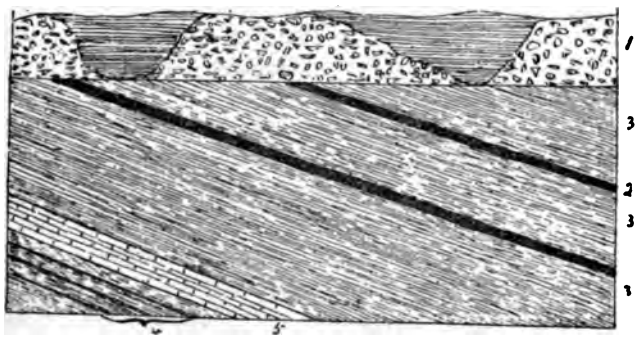


FIG. 1.—HEWITT'S PIT, FENTON LOW.

1. Boulder Clay with pot-holes of sand.
2. Gutter or Fenton Low Coal.
3. Marls.
4. Thin Coals.
5. Fine Sandstone.

magnificent one of 90 feet, and shows at the top about nine feet of Boulder Clay lying unconformably on the Coal-Measures, which dip S.W. at about 15°. The Boulder Clay contains many local ice-scratched rocks, and is very stiff. It contains pockets of pure fine sand, and is overlaid at the east side of the pit by sand and gravel corresponding to the beds at Bucknall. Chalk flints have been found here on former occasions by the Director, and the remains of a mammoth were exhumed from these pits a few years ago, the tusk being in the possession of Mr. James Ward. Just below the Drift at the west side is the Fenton Low or Gutter Coal (2). This is the uppermost workable coal in the Pottery Coalfield, and evidences of old workings have been come across by the

present owners. It is a matter of interest that Josiah Wedgewood's earliest factory was on this site, and some fossil saggars and other potting relics have been unearthed. Below the Gutter Coal are marls 20 feet thick; then there is seen an impure coal 16 inches thick (3); then follow 20 feet of marls, which rest upon a bed of fine sandstone very prolific in plant-remains (5), six feet thick; and below this are marls with three thin coals, and then about 15 feet of marls to the base of the quarry. This is close on the marine band of *Spirorbis* Limestone, which could be reached a few yards below the present floor. The marls are, in places, very fossiliferous, being full of *Calamites*, *Sigillaria*, ferns, and other organic remains. Some rare fossil ferns have been obtained here.

About 100 yards further east is Messrs. Warrington's pit (Fig.

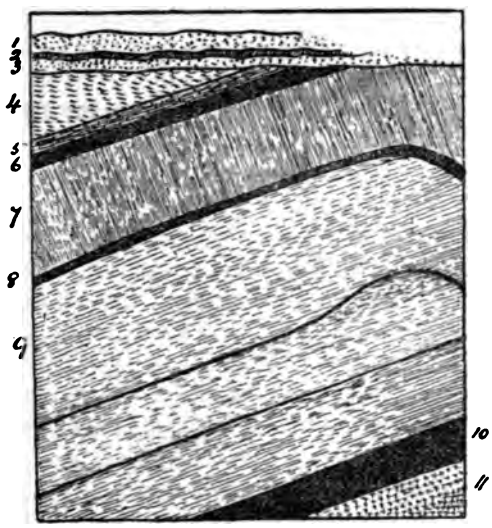


FIG. 2.—MR. WARRINGTON'S MARL PIT, FENTON LOW.

1. Upper bed of Boulder Clay.
2. Middle Glacial Sands.
3. Lower bed of Boulder Clay.
4. Marl.
5. Bassimine Ironstone.
6. Bassimine Coal.
7. Bassimine Marl.
8. Little Mine Coal.
9. Little Mine Marls, with thin bands of Ironstone.
10. Peacock Coal.
11. Peacock Marl.

2), to which the party now adjourned. The pit shows a section of over 100 feet in depth, extending 100 yards east and west. The Drift beds are of high interest, and consist of (1) an Upper

Boulder Clay, stiff clay with ice-scratched and angular fragments; (2) a middle bed of stratified sand and gravel varying from two to four feet thick; and (3) a Lower Boulder Clay, stiff, blue, and full of glaciated stones. This latter bed shows a very clean junction with the under-lying beds; the ironstone and coal beds immediately underneath being bevelled off at an angle of 10° till they disappear. The middle bed of stratified sand corresponds to the similar beds visited earlier in the day. In none of them have any fossil shells been found. The Carboniferous section is altogether in the Middle Coal-Measures, the exact top of which is not seen, as the *Spirorbi* Limestone band should crop out midway between the two pits, 12 yards above the Bassymine Ironstone; but the uppermost bed exposed beneath the Boulder Clay is a few feet of marls above the Bassymine (4). Then comes the Bassymine Ironstone (5), a black-band ironstone four feet thick, the term black-band signifying that it contains enough carbonaceous matter for calcining. This is brittle and shaley, and is full of impressions of *Anthracomya phillipsii*. The Ironstone lies immediately upon the Bassymine Coal (6). This condition of things obtains over and over again in the coalfield ironstones, with corresponding coal lying contiguously and contributing much to economy in mining. Below the Bassymine Coal are about 30 feet of grey and variegated marls (7), with ironstone nodules, containing fossil plant-remains. Then is seen the Little Mine coal (8), about two feet thick. Below this is 20 feet of yellowish nodular marl, with nodules of clay-ironstone (9). This rests on a band of black shale six inches thick, which, towards the east, gives a curve upwards, and does not follow the line of stratification of the other beds. Below this is ten feet of grey marl, the most fossiliferous bed in the quarry, full of ferns (*Neuropteris Hofmanii* being very common), *Calamites* and other plant-remains. Then is seen a band of shaley ironstone nine inches thick, regularly stratified, and then 15 feet of grey marl; and at the bottom of the pit the Peacock Coal (10) four feet, one of the most constant members of the coalfield.

One mile-and-a-half south-east another section on the same horizon was visited at Messrs. Cope's pits, Longton. Here the section includes the *Spirorbis* Limestone, the base of the Upper Measures.

Votes of thanks were passed to the owners of the various pits on leaving. Adjournment was then made for lunch, after which Mr. J. Ward, F.G.S., exhibited his collection of fossil fish from

the North Staffordshire Coalfield. The collection contains a large number of type-specimens, and is very rich in numbers, as well as in unique examples.

A start was then made for Trentham, the seat of the Duke of Sutherland, where the party were received by Messrs. Collins and Kirkley, and conducted through the park to Spring Valley, a picturesque dell, where are exposed some red rocks, beneath which issues a fine spring of water. The age of these rocks formed a topic of discussion, as to whether they were to be classed as Upper Carboniferous or Permian. They are mapped as the latter. The President seemed to think that they resembled very closely rocks which, in Cumberland, he had mapped as Carboniferous. Working north-west up the dingle, beds of Bunter Conglomerate were seen, overgrown by luxuriant herbage, and crowned by woods. The fall gradually ascended till the party debouched on the top of the Bunter Pebble ridge. At the west end of the ridge is a fine section, 100 feet in depth, showing beds of sand and pebbles, with much evidence of current-bedding.

This quarry has been geologically visited on several occasions, and has yielded the usual derived fossils from Silurian and Carboniferous beds; and, in addition, a block of quartzite, containing *Orthis redux* and many decomposed agates. The pebbles all bear the curious pitted mark characteristic of these beds. The carriages were then mounted for a short distance (about one mile) south-west of this pit, and two trap dykes crossing the road from Hanchurch to Stableford were exposed by some members of the party. They were in Bunter beds, and their limits were well marked, they being apparently about nine and three feet wide respectively. The trap was much decomposed and friable, but a few solid pieces were obtained. These beds have since been traced N.N.E. and S.S.W. for over half-a-mile. The distance between the dykes is about 40 yards. The dykes themselves vary much in thickness at various places. The rock is a basalt, with crystals of olivine, labradorite, etc. Having made good the damage done to the roadside, a start was made for Stoke, driving *viâ* Oak Hill and Tenktull, to see the outcrop of Permian Sandstone, and to obtain a view of the Trent and Foulbay Brook valleys, which are here very wide, and have well-marked boundaries. The President suggested that there had probably been a lake here, and this view received confirmation from the great depth of river deposit, 40 feet, and the great area of its distribution in the valley.

Second Day.—An early start was made for North Rode, where the party alighted and proceeded south down the line to the Viaduct over the River Dane, the county boundary between Staffordshire and



Fig. 3.—Section in the Dane.

[From 'Geological Survey Memoir.']

1. Thin, red, marly sandstones, ripple-marked, bent and faulted ... } Upper Keuper.
2. Red and white sandstones ... ... } Lower Keuper or Water-stones.
3. Thick bedded white sandstone ... } Lower Keuper or Water-stones.
4. Black shales and ironstone ... Yoredale Rocks.
a. River-Gravel.
R. Railway-Viaduct.

Cheshire. Here the section (Fig. 3) of Keuper beds was seen cut off about one hundred yards from the Viaduct and faulted against Yoredale shales, full of compound *Goniatites* and tilted almost vertical. Immediately under the Viaduct are seen the red marly

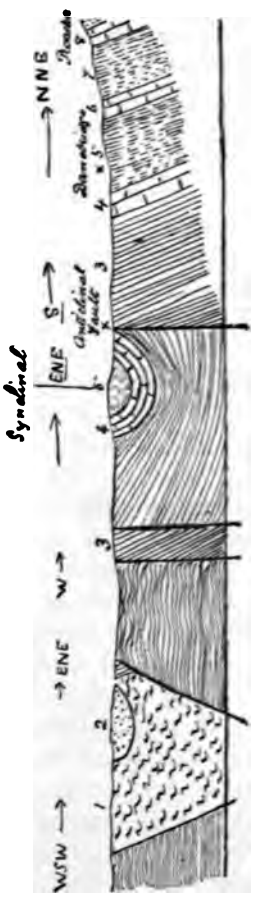


FIG. 4.—SEMI-DIAGRAMMATIC SECTION OF DANE VALLEY, FROM PECK'S HOUSE TO BACK FOREST.

[Scale about ½ inch to mile.]

1. Permian.
2. Bunter Beds.
3. Yoredale Shales and Sandstones.
4. 5th Grit.
5. Grit Shales.
6. 4th Grit.
7. Grit Shales.
8. 3rd Grit.

sandstones, ripple-marked, bent, and faulted, of the Upper Keuper. A few yards east the members of the Lower Keuper crop out in succession (Waterstones). The immediate line of the fault is overlaid by river-gravel, but it can be localized to within a few yards. This fault is the Red Rock fault mentioned above as forming the western boundary of the North Staffordshire Coalfield. The party then walked by a private road to Bosley, where a picturesque

little gorge and a series of small waterfalls is seen in Yoredale beds of alternating sandstones and shales. Here carriages were in waiting and conveyed the party to Rushton, where sections showing outliers of Bunter and Permian beds were seen lying in due succession in a hollow in the Yoredales (Fig. 4). At this point the Dane Valley was entered, a most picturesque dale with cliffs of Yoredale shales and sandstones, one hundred feet high, dipping east, and covered with woods. The valley is two miles long, and the scenery is entrancing. A succession of Yoredale beds are seen for the first mile, when the fifth, or lower bed of Millstone Grit appears, dipping east, at the first salmon ladder. This is one arm of a synclinal and is followed by the shales immediately above it, which soon bend gently and dip west, the fifth grit soon re-appearing, and beneath it come the Yoredale shales again. The grit beds are beautifully seen in the bed of the river, and this most interesting geological section is situated in the most lovely spot in the valley. About 200 yards eastward the Yoredale beds are much contorted, and the position of the anticlinal fault which runs from Staleybridge to Leek can be made out. The shales here are fossiliferous, and contain *Aviculopecten papyraceus*, *Posidonia gibsoni*, *Goniatites listeri*, and scales of *Acrolepis*.

After having examined the fault further east in the river-bed the fifth grit again appears dipping east, and is succeeded by grit shales, a good section of which were seen on the east side of Dane Bridge. Here carriages were in waiting and conveyed the party to Swythamley Hall, visiting on the way a quarry in the fifth grit in which were some huge concretions, and a very interesting example of a thick bed of gritstone suddenly paying out was observed. Swythamley Hall is the seat of P. Brocklehurst, Esq., who had kindly thrown open his house and grounds to the Association, who by his courtesy lunched in the riding school, after which they were conducted through the house and grounds, and inspected a most interesting collection of local relics of the '45 and geological curiosities, amongst which were shells from the drift of Clulow Cross. Mr. Brocklehurst had written to express his sorrow that he was away from home, and not able to receive the party in person. After a hearty vote of thanks, Mr. Smith Woodward, sen., conducted the party over the moors to Lud Church. *En route* the escarpments of the fourth and third grits were crossed, the intervening shales having suffered denudation. From this *point a most interesting* view of the hills north and the broad

geological features of the district were examined. Lud Church is a remarkable chasm in the third bed of grit, and I cannot do better than quote Professor A. H. Green's description of it in the Geological Survey Memoir of this district: "It is a rent running through the solid grit in the line of strike, for about 150 yards, from 30 to 40 feet deep, with a breadth of from 6 to 15 feet. The walls are vertical or overhanging, and it gives the idea that the front of the hill has parted bodily from the main mass, and slipped a little forward, leaving this fissure along the line of fracture." This view is borne out by the fact that the opposite walls of the fissure correspond, and that at each end the fissure is considerably narrowed and continued for some yards. The place may easily be missed, and from the top would not be noticed till stepped into. The origin of the name is supposed to be due to its furnishing a hiding place for the Lollards. Opposite the entrance is a fine weathered piece of fissure rock. Castle Cliff Rock, which overlooks the Dane. On the walk back to the Hall the Hanging Stone was visited. This is a overhanging massive block of grit (fourth grit) that has been weathered out.

Carriages then conveyed the party through Swythamley Park to Gun Hill quarries (Yoredale Sandstone), situated at the apex of the anticlinal fault which had been seen in the Dane Valley during the morning. Here the curious naturally bored concretions, and other concretions were seen, which formed the subject of a paper by the Director read before the Association in March, 1890.* The quarry is most interesting, as it shows the anticlinal fault and good examples of many forms of disturbance of strata. Here the Association was met by Mr. Enoch J. P., of Leek, who had specially ridden out to welcome them on behalf of the local scientific gentlemen. A drive of about six miles brought the party to Leek, the moorland town famous for its silk industry, an outcrop of Bunter Sandstone with few pebbles. Good buildings are seen in the streets. Head-quarters were at the Red Lion.

THIRD DAY.—A visit was made to the Roaches. Here are the outcrops of the different grit-beds which lie in the form of a basin, the intervening shales having been much denuded by weathering, leaving the grits in successive escarpments. The rocks are weathered in many fantastic forms, and are very picturesque, and rise to over 1,500 feet.

* *Vide supra*, p. 422.

Alighting near Upper Holme, the Upper Yoredale Shales were seen in a small stream, and walking north the outcrops of the fifth and fourth grit with intervening shales were noticed. Then a hard climb over the rocks brought the party to the top of Hencloud, (third grit), where a magnificent panorama opened out to view. Here the geological features of the whole district could be made out and the eye could follow the different grit outcrops on each side of the basin, with a small coalfield in the centre (Goldsitch) and the Yoredale beds rolling down west from Morredge and re-appearing from beneath the grits, and rolling up to form the east portions of the Gun Hill anticlinal. The weather was fine, and the view magnificent, and afforded a fine demonstration of the surface configuration of the country.

Later on in the day Mr. Brough received the Members to tea, and conducted them over his grounds, and to the Yoredale sandstone quarries on Leek Waste, where many remains of plant-life were seen.

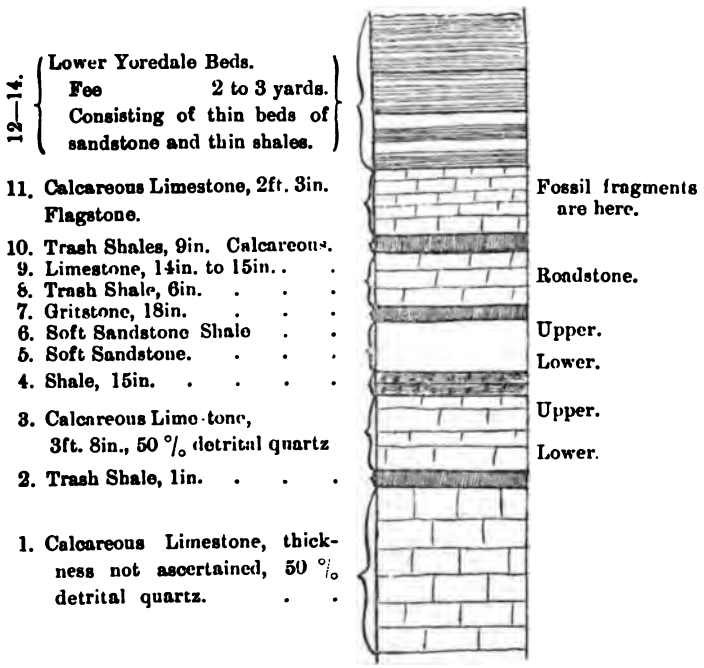


FIG. 5.—BUTTERTON MOOR QUARRY.

Fourth Day.—This was devoted to an explanation of the limestone country and the passage beds between the Yoredale beds and marine limestone. Under the directorship of Mr. Wardle, F.G.S., the first section visited was at Butterton Moor (Fig. 5), which was viewed under the difficulties of wind and sleet. A description of this section is to be found in the paper read to the Members by Mr. Wardle in the evening. A move was then made to Grindon, where, after a brief time for lunch, the party set out to walk to Beeston Tor, passing on the way the contorted section of Carboniferous Limestone shown in Fig. 6. The route led over the hill down into the junction of the Hamps and Manifold valleys, at which point the beds of the streams were dry, the water having disappeared down swallow-holes, each of which were subsequently visited. The valley is very beautiful, beetling crags of limestone overhanging its sides, in which are the entrances to some small caves. The bedding of the limestone is well seen in the dry river-beds, with several seams of chert. During winter and floods the beds are full of water. Curiously the two rivers re-appear in Ilain Park within a few yards of each other, at a distance of about five miles direct from the points at which they disappear. Walking down the valley, along the dry bed of the stream for about one mile, in the midst of exquisite scenery, the magnificent entrance of Thor's Cave was seen at the top of the cliff overlooking the valley. After a stiffish climb the cave was reached, and a brief account of its exploration was given, and of finds of mammalian bones, but no thorough search was conducted, and much of interest is still doubtless buried under the stalactite floor. On descending into the valley, about a quarter of a mile north, the swallow-hole of the Manifold was seen. This is not anything like the swallow-holes of Yorkshire, but the water gradually disappears



Fig. 6.—Section in Carboniferous Limestone on road from the Red Cow Inn, Grindon, to Beeston Tor.

through fissures apparently between the lines of bedding. Ascending by a narrow wooded path to Grindon, carriages were remounted and a move made to Waterhouses, where the swallow-hole of the Hamps usually is; but there appeared to be more water than the fissures could manage, and consequently the river did not wholly disappear. The quarries here are very fossiliferous, and various species of *Productus*, *Spirifer* and other Carboniferous Limestone species were obtained. In a fissure in the limestone here, the Director, some years ago, discovered the almost perfect skeleton of a mammoth. After a short time spent in hammering, a move was made for Cauldon Low, which is part of the Weaver range.

Here and there at the base of the hills of this range occur curious beds of fire-clay and stratified gravel and sand. These have been the subject of discussion. The pebbles seem to be derived chiefly from Bunter beds, but there is little doubt that they have been re-arranged. The probable age of the beds must be referred to Glacial times, but of late years little work has been done at them. They appear to lie in cavities in the Mountain Limestone, and are at a considerable elevation about the river-valleys. A detailed section cannot be published at present, but it will probably be brought before the Association in the form of a note at some subsequent meeting.

A view only was obtained of the extensive limestone quarry of Cauldon Low, owing to the lateness of the hour; and, owing to a misunderstanding, preparations had not been made to convey the party to Froghall by the tramway, so that the section of the whole of the Carboniferous measures up to the lower coal shales was missed, but instead, the party had an adventurous drive home, one which I think few will ever forget. One of the Jehus, having poured down copious libations in honour of Bacchus, would persist in driving in the ditch, and various other vagaries, on a road which is not the safest at the best of times owing to the inclines. After several hairbreadth escapes of turning over, a fierce onslaught was made, and the unlucky Jarvey was dragged from his lofty throne, carefully guarded by two members of the party, and was placed under the seat until after a sleep, and on nearing Leek, he was allowed to again take the ribbons and bring the party in with all the honours.

After dinner a visit was paid to the Nicholson Institution, lighted up and thrown open till a late hour in honour of the visit.

A splendid collection of Carboniferous Limestone fossils was on view, and Mr. T. Wardle gave the following paper which was illustrated by the limelight lantern, and various specimens and samples) on the Butterton Moor quarry visited early in the day. The President, Mr. T. V. Holmes, occupied the chair, and at the end of the paper made a few remarks, in the course of which he thanked the local men who had received and assisted in the work of the Association.

"The Yoredales occupy a middle position between the Mountain Limestone which underlies them, and the Millstone Grit above them. They are divided into three groups: the lowest, black shales with thin, black, earthy limestones about 2,000 feet thick; the middle group, a thick mass of hard, unbedded, fine sandstones, here and there semi-crystalline, as at Grin Hill, with partings and thick beds of black shale; the upper group, shales, thin limestones, a thick sandstone called the Millstone of Fairy, and grey, sandy, micaceous shales, attaining with the middle group another 2,000 feet. Next above, there is the Millstone Grit, a name suggestive of one of the purposes for which these rocks are quarried. The thickness assigned to this group is about 1,000 feet. The lowest member is the fourth or Kinder Scout Grit; it is generally in two beds, and is from 7.0 to 1.0. feet thick, and separated from the third or Roaches Grit by thick shale. Over the third grit occurs shale, and above this the second grit or Hallingden flags, 100 to 120 feet thick, then shales, and then the uppermost or first grit, commonly known as rough rock. I think the beds I am going to describe belong to the upper part of the Lower Yoredale, though they may be the lower part of the middle series. On the top of Butterton Moor are several quarries near to each other and near to the road from Onecote to Longsdon. In these quarries the following measures occur, from the top downwards:—1, one yard, thin sandstone coming to the surface. 2, 13in. compact gritstone used for walls. More coarse sandstone, the granules of white transparent quartz cemented by limestone, more quartz than limestone. There is much carbonaceous matter, possibly detrital vegetable remains. The quartz granules are only slightly waterworn. 3. Thin shales and thin flags. 4, 20in. flagstones from which large flags are got. I have a good specimen here, the upper face of which is covered with innumerable fragments of Brachiopodous shells, a characteristic feature of the

surface of the flags of this bed. It is a limestone grit, effervescing strongly with hydrochloric acid. It splits up into thin laminæ, and is used for roofing. A portion is more compact and less flaggy, and is used for sets. Numerous spines of *Brachiopoda*, probably *Productus semi-reticulatus*, occur in this part of the bed. It is more closely grained than 2, and has more carbonaceous matter, resembling the infiltration of very finely comminuted black shales, the whole firmly cemented by limestone filling every interstice. The detrital quartz grains are coarser, with fragments of marine shells, and vegetation. 5, 10 inches blackish, thin, sandy shales. 6, 18 inches, gritty limestone like 4, but quartz smaller, more angular and lanceolated, used for roads. 7, 5 inches, shale and thin flags. 8, 17 inches, of what looks like gritstone, used for paving sets. The upper part effervesces less than the lower, which is coarser, scarcely fossiliferous, but carbonaceous. 9, a thin shale parting. 10, 12 inches soft sandstone. 11, 5 inches soft sandstone shale. 12, 8 feet 7 inches, hard, compact rock, classed as limestone in the Geological Survey Maps. It consists of one half sedimentary water-worn sandstone, and one half limestone. It is extremely hard and compact, sub-crystalline, with a conchoidal fracture like true limestone. The lower part is closer in texture, and effervesces more strongly. The stratification of the sand beds comes into view when the lime is dissolved away. 13, thin parting of sandy shale, finely laminated. 14, a much thicker bed than 12, closer grained, but otherwise resembling it strongly. No iron is noticeable in these beds, but percolation of iron from above has given an ochreous tint to bedding surfaces. Most interesting is the profusion and admixture of small fragments of plants and shells, most numerous in the iron-tinted parts. They are angular and fresh looking."

"I would suggest that these Butterton Moor silicified limestones, or more properly limestonized gritstones, are theoretically the best road-forming rocks. In North Staffordshire we find that roads formed exclusively of sedimentary grits such as the upper Yoredale strata, the best of which is probably the hard quartzite bed known as the Gun Hill Sandstone which seems to have undergone a sub-crystallization since its deposition, take too long a time to consolidate in road mending. In fact, in the more rainy and hilly moorland districts they never have true cohesion; whilst the roads formed of limestone alone become very greasy and mud-bound in wet weather and painfully dusty in dry windy seasons of

the year, in addition to being deficient in lasting or wearing qualities. I would urge that, now that the true composition of these beds is ascertained, trials should be made to see whether the known binding property of limestone and its cementing action in the presence of larger fragments even of itself would not also similarly act in the presence of other rock, as was specially the case when these beds containing so much detrital quartz were originally formed; and whether these rocks, therefore, could not be successfully applied to road making and mending. I believe the result would be to give us roads which would be more durable and freer from the defects I have just mentioned. I think the good properties of each kind of rock would be incorporated greatly to the minimizing of their defective ones when not in combination, and I predict an important usefulness in these beds for this purpose."

"I will now say a few words on the *Foraminifera* of the Mountain Limestone. The Waterhouse Limestone we have seen to-day abounds in microscopic protozoic life, the whole substance of the limestone being sometimes made of these organisms. The known *Foraminifera* of the Mountain Limestone comprise thirty genera, of which the best known are the following:—*Trochammina*, once called *Cornuspira*, *Dentalina*, *Endothyra*; the characteristic limestone form *Globigerinida*, like the *Globigerina* of the deep-sea "Challenger" dredgings, *Lagena*, *Nodosaria*, *Textularia*, and *Nummularia*. Of these thirty genera, fifty species are known. A characteristic limestone form is *Endothyra*. I have found it in the Black Marble of Ashford, near Bakewell and the neighbouring limestones. In the Buxton Limestone I have found *Textularia*. In other slides under the microscopes are *Valvulina*, *Archæodiscus*, *Saccamian*, and *Carteria* in the Waterhouse sections. The occurrence of microzoan forms is partial rather than general, colonies being often met with, rather than a general distribution. The large quarries at Cauldon Low are, for some reason or other, sparsely populated, whilst the parish of Grindon, to use the words of a late Vicar, is nothing but fossils. The Mountain Limestone is not so microzoic as the Chalk, which is made up of them; but it has been chiefly built up by crinoids, corals, and mollusks. We must not forget the great solvent powers of carbonic acid under the pressure of great ocean depths. Water so charged would dissolve the shells and skeleton microzoan forms and redeposit them in an amorphous form on elevation of

temperature or other changing physical conditions; so Cauldon Low Limestone may be of the deep sea, and the thinner and more crinoidal limestone of Waterhouses shallow sea limestone. In 1873 I examined the limestone of this neighbourhood. Out of 30lbs. of limestone dissolved in hydrochloric acid, I got 300 grains of mud, mostly alumina, and 1,269 grains, or nearly three ounces, of microscopic crystals of quartz, six-sided prisma terminated by six-sided pyramids. They are always perfectly crystallized, translucent, and very interesting objects, averaging in measurement about the 400th of an inch in length, and 10th of an inch in breadth. The smallest are less than 1,000th of an inch long. Near Buxton they are larger and slightly corroded or worn. At Waterhouses they are somewhat amorphous. The encrinital slabs contain these crystals, but I have never found them in Chalk, Lias, Oolite or Silurian Limestones. It is difficult to see why the silica should be in perfect crystals in some places, and at other places, like Bakewell and Matlock, should occur as amorphous stratified chert. The chert chiefly occurs in the upper beds, the crystals in the lower."

Fifth Day.—Director: Mr. F. Barke. Leaving Leek at 8.50, *viâ* Stoke, Mowcop Station was reached about 10.15. Here the party were met by the Manager of the Ashbury Hydraulic Lime Works, who conducted the Members to the offices, where some specimens of minerals and fossils obtained from the workings were seen. On the surface is a large exposure of Drift clays.

The Mountain Limestone here is brought up to the surface, with a throw of about 8,000 feet, by two faults—one, the Red Rock fault of the Cheshire plain; the other, a local one, and less extensive. The whole will be well understood by the section from the Survey Memoir (Fig. 7). The stone is worked by a tunnel driven horizontally into the hill for about 800 yards. The tunnel crosses the Red Rock fault, but the exact locality cannot be seen because, owing to the disintegration of the rock at the fault itself, the passage is there carefully bricked.

The party were conveyed into the workings by a train of trollies drawn by a horse. On arriving at the workings, the Members were conducted round, and the geological features, small faults, etc., pointed out. An interesting bed of coral (*Lithostrotion martini*), several feet thick, was observed. During the visit a shot was fired by one Member of the party, and the method of

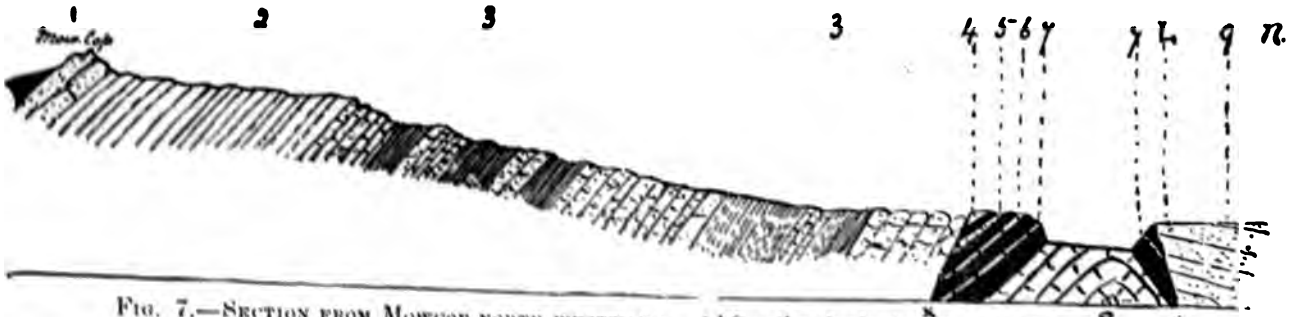


FIG. 7.—SECTION FROM MOWCOP NORTH-WESTWARD. (After the Geological Survey Memoir.)

			Estimated thickness in feet.
Millstone Grit		1. Third Grit	100
Yoredale Rocks	Middle Group.	2. Shales probably, but no section	500
		3. Thin bedded, fine, hard sandstones and shales	1,400
		4. Hard, reddish-yellow sandstone	
		5. Dark sandy shale	20
		6. Impure Cannel Coal	1
	Lowest Group.	7. Shales with thin earthy limestones	120
Mountain Limestone		8. Limestones with thin shale partings.	

× Fault.

\+ Red Rock Fault.

L. Limekiln Farm.

R. Lower Keuper Sandstone.

winning the stone explained. On emerging into daylight once again, the party was entertained at a sumptuous luncheon kindly provided by the directors, after which votes of thanks were passed, and a move was made for Grotto Wood, about one mile south, where the Red Rock fault was exposed by a few minutes' digging in the bank of the lane. The line of fault is remarkably distinct here, the black Carboniferous shales lying faulted against Keuper sandstones. Higher up the lane was an exposure of Coal-Measure sandstone, and about a quarter of a mile west a large Keuper sandstone quarry, whence the railway had obtained a good deal of stone during the construction of their line. From this point the ascent of Mowcop (1,100 feet) was made, from the long ridge of which was obtained a splendid view of the Cheshire plain to the west, the Macclesfield Hills and Cloud on the north, and to the east the Biddulph Valley and Monedge. From this point nearly all the ground covered by the Association in the previous days could be reviewed. The ridge itself is formed of the first grit towards the south, but further north the third grit crops out, and a good section of the intervening shales was seen. The coal beneath the first grit has been worked here, and its position was demonstrated. Walking north along the ridge several quarries in the grit were examined, in one of which was an interesting light-coloured shale bed about six feet thick. The ridge is continued under the name of Congleton Edge. It is seen that the ridge is one arm of a synclinal trough, the other arm forming a ridge on the east side of the intervening valley, which is partially filled up by Coal-Measures, the northern extension of the Pottery Coalfield (the Biddulph trough). A pleasant walk along the ridge and a gradual descent brought the party to Congleton, when it was found that time would not allow the completion of the programme or the ascent of Cloud (third grit), 1,190 feet. After tea at Congleton, which is built in the Cheshire plain, train was taken for Stoke and London, and the Excursion was brought to a close.

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VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

SATURDAY, 12TH APRIL, 1890.

DEMONSTRATION ON THE FOSSIL ECHINODERMATA, BY F. A. BATHER, M.A., F.G.S., AND J. W. GREGORY, F.G.S.

(*Report by* THE DIRECTORS.)

The Members of the Association, joined by those of the London Amateur Scientific Society, met in Gallery No. 8 of the Geological Department, where the fossil Echinoderms are now displayed in six table-cases and four wall-cases, the former devoted to British and the latter chiefly to foreign specimens.

Mr. Bather first spoke on the Crinoidea.

The table-case next the door (No. 73) is partly devoted to a series explaining the structure of the Crinoidea, with special reference to such parts as are found in a fossil state. In this series the labels are consecutive, and specimens or drawings are used in illustration of the text, not *vice versâ*. This is succeeded by the British fossil crinoids arranged in zoological order under the main stratigraphical divisions. The details of exhibition are not yet completed, but enough has been done to show the plan it is intended to follow. Under each family name is given the diagnosis and references to the chief sources of information. Under each genus is given a diagnosis and references, then follow preparations supplemented by drawings, which show all the structural details of the genus. Each species of the genus is represented by a good characteristic specimen, and attention is

directed by drawings and preparations to the diagnostic features of the species. In the cases of abundant and variable species, such as *Marsupites testudinarius*, some attempt is made to trace the chief variations of form; but as a rule the mass of material is arranged in the drawers, where it is more immediately available for scientific research.

In wall-case XVIII, special attention is paid to genera that are not found in Britain, and those specimens are exhibited that help to elucidate structure or habits, rather than specimens showing minute specific characters which cannot possibly be distinguished at such a distance. It is also necessary to place in the wall-cases specimens too large to be stowed away elsewhere; some of these are very beautiful colonies of crinoids, others are of small value, but as darkness obscures the greater number their relative worth is unimportant.

The collection is not rich in types; few, indeed, of the British fossil crinoids have been described, and many original specimens are untraceable; but the material here collected is very abundant. Of foreign crinoids, those of the American Carboniferous are best represented.

Attention was drawn to several remarkable forms of Crinoidea, of which the Museum possesses fine specimens, *e.g.*, *Crotalocrinus*, with its net-like arms; *Herpetocrinus*, with coiled stem and minute crown; *Calceocrinus*, with the crown drooping down the stem; and *Eucladocrinus*, with its twisted stem of elliptical ossicles.

Other specimens were alluded to as illustrating the natural history of the Crinoidea, and a leaflet on this subject was distributed to Members.*

Mr. Gregory then spoke on the Echinozoa, directing attention chiefly to the British collection, which occupies table-cases 75 to 78.

The Holothuria, as is natural, are represented by but a few spicules.

The Asteroidea include a number of valuable types figured by Forbes, Dixon, Wright, and Carpenter, and the originals of Mr. Sladen's forthcoming monograph. It was pointed out that the generic names hitherto employed by palæontologists would have to be extensively altered, and that the group of species included

* Since published in 'Proc. London Amat. Sci. Soc.,' i, pp. 32-3, Oct., 1890.

under *Astropecten* would have to be divided among such genera as *Nymphaster*, while most of the Jurassic and Eocene forms must be relegated to the Archasteridæ. The foreign collection includes some important types from the Devonian of Bundenbach, though most of those in the possession of the Museum have not yet passed into the general collection.

The Ophiuroidea include most of the originals of Wright and Forbes.

The Echinoidea are probably of most interest to the geologist, and of this class there is a very extensive and valuable collection, illustrating its evolution in English seas. Here, as throughout the gallery, the specimens are arranged stratigraphically, in order to illustrate the faunas of the successive geological systems. The Mesozoic Echinoidea in table-cases 76 to 78 form the best series, one which well illustrates the succession of the faunas, and enables a good comparison to be made of the same families at different periods. Of some of the more important species, a sufficient number of specimens have been exhibited to give an idea of the wide range of specific variation. The specimens of *Micraster cor-anguinum*, *Echinocorys scutatus* (=*Ananchytes ovatus*), and the Jurassic *Clypeus* and *Hemicidaris* may specially be studied from this point of view. The Mesozoic collection is rich in valuable types, since it contains most of those figured in the monographs of Dr. Wright and in Dixon's 'Sussex,' and many of those of the Decades of the Geological Survey and various scattered papers. Many of these specimens are of value as illustrating important points of structure, such as *Cidaris edwardsi* from the Lias, the toothed *Holectypi*, and the fragments of *Pelanechinus* and *Echinothuria*.

The collection of Tertiary Echinoidea, though small, includes nearly all the types. The Eocene species form a dwarfed tropical fauna, while the Pliocene had a close affinity to the fauna still living in the Caribbean Sea.

EXCURSION TO POTTERS BAR AND HATFIELD, FOR POTTERELL'S PARK.

SATURDAY AFTERNOON, 19TH APRIL, 1890.

(In conjunction with the Hertfordshire Natural History Society.)

Directors: UPFIELD GREEN, F.G.S., and DR. MORISON, F.G.S.

(*Report by* THE DIRECTORS.)

The party assembled at Potter's Bar and walked by way of Mimms Hall and Warren Gate to Potterell's Park. From Mimms Hall the walk was by the side of the bourne which drains the London Clay area on the south. In Potterell's Park are some large cavities or swallow-holes, through which the water generally descends into the Chalk. On Saturday the bourne was very dry, and the stream did not flow into the holes. Assembled on the slope of the dell in which the swallow-holes are situated, Mr. Upfield Green alluded to the loss the party were sustaining by the absence, through an accident, of Mr Hopkinson, who was to have acted as conductor. He had, however, sent the following paper :—

"It is a very general rule that the name of a river is retained to the head of its largest branch, which, bringing down the greatest quantity of water, drains the largest area. If there is a deviation from this rule it is when the largest stream takes an abrupt turn, the name then sometimes being carried by a smaller stream which takes a more direct course. It has been pointed out that to comply with this rule the name Colne ought to have been carried up to the stream known as the Ver, for not only is the Ver a much larger river than the Colne at the junction of the two streams, but it also maintains the general direction of the united stream quite as much as does the Colne. That the Colne, above here, was a smaller river than its tributary the Ver was remarked upon as far back as the year 1700, for Chauncy, in his 'Historical Antiquities of Hertfordshire,' says : 'The Colne, which springs forth near Tittenhanger, then passeth the road near Colney Street, and running above two miles in length, meets the Verlume (Ver) near Park Street, but though the Verlume is much the greater stream,

yet the Colne usurps the glory of her own name, and flows thence to Watford.' I am not aware that any explanation of this anomaly has yet been offered, but I think that we may possibly have a key to it at this spot. The swallow-holes here absorb most of the drainage of about 40 square miles, the stream from the south draining about 35 square miles, and that from the north about five. The whole of the London Clay area between Bell Bar, Northaw, Potter's Bar, Chipping Barnet, Ridge, and Shenley is drained by the southern stream; while the northern drains the area between Bell Bar, Hatfield, and Welham Green. A glance at a geological map will show that these streams and their tributaries have materially altered the configuration of the country, the northern stream, which has several small tributaries flowing from under the Glacial gravel in Hatfield Park, having completely cut through the Tertiaries so as to cut off the Reading beds from the main mass and form of them an 'outlier' between Hatfield and North Mimms; and the southern stream and one of its branches having nearly made an outlier of the London Clay and Reading beds between North and South Mimms and Shenley. Let us consider one of the results of this. These rivers, at one time flowing throughout their course over impervious London Clay, have now cut down their beds to the Chalk for some distance (the northern stream entirely), and when this is the case we know that water no longer flows on the surface unless the plane of saturation in the Chalk comes to the surface. The Chalk being permeable, absorbs the water and becomes saturated, the plane of saturation rising slightly from the valleys towards the hills. But the Chalk absorbs water very slowly, and therefore, after heavy rain, water may flow for a time in a Chalk river-bed when the plane of saturation does not come up to this bed. Some of the water in the gravel, imperceptibly sinking into the Chalk while there is sufficient to spare to form a river on the surface, but sooner or later the water will find a more rapid way into the Chalk than through mere absorption. A weak spot is met with and soon wears the water. Having once found a way, almost every year enlarges the crevice by the mechanical results and chemical dissolution of the Chalk, and thus 'swallow-holes' appear on the surface, and 'pipes' form underground. At first there may be merely more rapid percolation, the pipe filling with gravel and sand, and the impervious portion of the

Chalk, such as flints, but in course of time a channel is sometimes formed, as in several 'swallow-holes' here, down which the water rushes to the plane of saturation with ever-increasing volume. At this spot there are channels which the water has gradually made for itself down which a man might be carried. I have seen these 'swallow-holes' when no water reached them; I have seen them when a powerful stream came from the south and rushed down in torrents with a roar which I heard long before I could see what was its cause; and I have seen them, or rather the spot where we know they are, when they were covered by a sheet of water forming a peaceful lake into which streams flowed from north and south, and out of which a stream flowed on through Mimms Park and into the permanent river of the Colne. Then, doubtless, the plane of saturation in the Chalk was raised to above the apertures of the 'swallow-holes,' in fact, to the level of the water in the lake. I do not know when these rivers received their names, but the Ver must have been so named when the Romans invaded Britain and founded the city of Verulam, and the Colne was probably named before the Ver. Even if we can only go back about 2,000 years, almost every day during that period the Colne and its tributaries above this point have been cutting their beds through the Tertiaries into the Chalk and so lessening the volume of water they convey above the surface, and these 'swallow-holes' have been enlarging. It may be asked: Has not the Ver been doing the same? It has not, for nowhere is it a stream flowing over clay; it is a Chalk stream from its source to its junction with the Colne, and it is not subject to floods as is the Colne. But this is not all. Lower down the valley, just above its junction with the Ver, the Colne must at one time have had its waters considerably augmented by a stream flowing out of Elstree Reservoir. In this stream there are now 'swallow-holes' which can usually take all the water which drains the London Clay area between Shenley, Elstree, Stanmore Heath, Letchmoor Heath, and Radlett. This water is now conveyed away artificially, and when it is required the swallow-holes have to be plugged. Moreover, along the margin where the Tertiaries cease to cover the Chalk, there are several other swallow-holes, not in the bed of any stream, but, nevertheless, conveying away water which would have formed streams flowing into the upper part of the Colne. Altogether we may add about 20 square miles to the 40 we had before, thus

making an area of about 60 square miles in the upper basin of the Colne now usually drained by swallow-holes or artificially conveyed into another channel, but long ago having formed streams which must have augmented the volume of the Colne above its junction with the Ver. Much of this water now finds its way into the Colne below the junction of the two streams; the springs at Otterspool, near Watford, which are known to many of the members of the two societies here present, are fed by it. Much of it is, doubtless, pumped up from the Chalk at waterworks and in numerous wells in Watford and Rickmansworth and their vicinity; but most doubtless flows on in the Chalk under the valley of the Thames. I think it will be evident that the Colne must, at some former period, have been, above its junction with the Ver, a much larger stream than it is now, while we have no reason to suppose that the volume of the Ver has materially decreased; and to this fact it seems likely to be due that the name of the Colne pertains to that which is now much the smaller stream. We have seen that it was smaller in Chauncy's time, nearly two centuries ago, but I think we have some evidence that the bed of the Colne was not, as it now is, usually dry through Mimms Park a century before then, when the fine mansion, known as North Mimms Place, was built. This now has, from its principal front, throughout the whole of the time during which residence in a country house is most enjoyable, the later spring, the summer, and autumn months, a view of a dry-river bed, in some places deep and wide; and I cannot imagine the house to have been built, situated as it is nearly facing the north, except that it might overlook a flowing river. The extent of variation of the source of the Colne is about 15 miles, from near Barnet Gate, midway between Chipping Barnet and Elstree, to a few field-lengths above Colney Street, where I have seen the river rise in a very dry year."

From Potterells Park a pleasant route was followed, Hatfield being reached about six o'clock. Tea was partaken of at the Temperance Hotel, after which Mr. Leighton proposed, and Mr. A. E. Gibbs seconded, a vote of thanks to Mr. Green for conducting the party, and to Mr. Hopkinson for his interesting paper.

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EXCURSION TO CRAYFORD.

SATURDAY, 3RD MAY, 1890.

Director : F. C. J. SPURRELL, F.G.S.

(*Report by* THE DIRECTOR.)

The Director met the Members at Crayford Station. Then passing along the Dover Road across the Cray marshes, where the old British and Roman road ran, the various sites were pointed out on either side of the stream, where early remains have been found from all ages up to the present. These remains showed that the ancient marsh was much narrower than at the present day, dwellings of Roman date standing on the gravel shores being now covered with alluvium. Somewhere about here the important battle of Creccanford was probably fought, but beyond the occasional finding of early Saxon ornaments no decisive discoveries have determined the exact spot. The pits were entered from the eastward by what was called Stoneham's Pit, now wholly arable land, as indeed the larger part of Rutter's is now. The party was detained for some time here by a good hunt in a prolific vein of shelly sand. Such fruitful sections have of late years become rare. The whole stretch of the clay cliffs from the chalk cliff, now being bared, to a point half-way across the old river-channel, presented an uninterrupted view of the old river beds. Vertically, they extend from the 100ft. contour line to below Ordnance Datum in mid-channel. The Director specially called attention to a layer of Till from five to seven feet in thickness intercalated with the sands near the cliff, along which it could be traced for some distance. It was full of stones, chalk, bones, etc., dragged from a former land surface and deposited in a mass or heap. The weight must have been considerable, as very many flints could be seen in it split to shivers. Other pits were pointed out, and the party repaired to tea at Erith.

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EXCURSION TO SWANSCOMBE

SATURDAY, 17TH MAY, 1890.

Director: F. C. J. SPURRELL, F.G.S.

(Report by THE DIRECTOR.)

The party alighted at Northfleet Station, from which could be well seen the pretty valley of Ebbsfleet, so renowned among antiquaries as thickly strewn by remains of Roman occupation, and in which, at the hamlet of Springhead, some are pleased to place the station called Vagniacæ.

An excellent view was obtained in a cutting leading to a chalk-pit on the left bank of a stream, half-a-mile from the station, of the lower brickearths, corresponding to those of Crayford and Grays (just opposite in Essex). The sands yield a similar fauna, though more limited and without shells. Palæolithic implements have been found, and a chipping place, in which the Director personally found many curious minor implements and flakes of a peculiar type, with an enormous quantity of flints of a very large size. From this pit progress was made to another on the same side of the stream, by the side of the road, near by. This consisted of masses of brickearth lying on gravel and having in the part further from the stream, masses of London Clay visible, which had slid into the stream. The London Clay is at present very far removed from the spot, which is a spur of Swanscombe Hill. Implements have been found in this brickearth, and teeth of *Elephas primigenius*. The brickearths lie upon the stream of gravel known as Dartford Gravel, which, from here, may be traced round Swanscombe Hill, becoming more marked in its character as it approaches the Thames. This higher level gravel was seen cut through by the Ebbsfleet on either bank, and on passing through Swanscombe village at Milton Street an extensive cutting for chalk and gravel enabled it to be carefully studied. The pit has produced a great abundance of flint implements, varying very much in size and workmanship, and again in the amount of wear they have received since fashioning. Bones have been obtained from this upper layer occasionally, and also from the blue clay leading down to the Thames, where, in a lower sand, gravel, and brickearth of the Erith age, both bones and implements have been found. The time did not admit of a visit to the graves which

covers the top of Swanscombe Hill, and the Members of the Association—having visited Swanscombe Church by the way, in which the Director drew attention to the bowl of the old carved font, sculptured from the local Upper Chalk, with flint discernible in its substance, a unique instance of the kind—partook of tea in the village of Greenhithe, and so to London.

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EXCURSION TO OXFORD.

WHIT-MONDAY AND TUESDAY, 26TH AND 27TH MAY, 1890.

Director: PROF. A. H. GREEN, M.A., F.R.S., ETC.

(*Report by* THE EXCURSION SECRETARY.)

SATURDAY, MAY 25TH.—The party assembled at noon at the station, and proceeded by train to Islip, under the direction of Prof. A. H. Green, F.R.S., etc., Professor of Geology in the University of Oxford. The railway-station at Islip is situated on the northern edge of the most southerly of a series of inliers of Lower Oolites in the Oxford Clay. These inliers lie on an axis of upheaval stretching in a N.E. and S.W. direction from Marsh Gibbon in Buckinghamshire to the district about to be described, the general dip of the beds being N.W. and S.E. on either side of the anticline. The Islip Noke inlier is further interesting from the fact that a line of fault, extending for many miles in a N.W. and S.E. direction (and of which more anon), cuts through it and

brings up the Great Oolite, which is not seen in any of the inliers further north. In the railway-cutting south of the station these beds were well seen, and fossils from the Cornbrash and Forest Marble collected. The Great Oolite is sometimes seen at the bottom of this section, which is, however, somewhat overgrown. Specimens of the peculiar so-called "*tracks*" were obtained from the Forest Marble, and a little round *Terebratula* from the Cornbrash, probably only a variety of *Terebratula oborata*, Sow. Many other fossils were collected. The Cornbrash when weathered appears as an earthy and rubbly limestone, almost brown in colour. It is seldom seen unweathered, in which condition it is said to be compact, and to possess the appearance of an ordinary Jurassic limestone, very different, indeed, from its typical mode of occurrence. The name "Cornbrash" is derived from its use for corn-growing upon heavy land. The Forest Marble is, in this district, a miscellaneous series of beds of shale, sandstone, oolitic limestone, etc., chiefly remarkable for variability and inconstancy within a limited area. Several pits showing the same series of beds were visited in and around the village of Islip, and upon both sides of the anticlinal dome; and the Great Oolite was seen in a pit near Noke, but not in a fossiliferous condition. More fossils were obtained and in better condition on the Noke side of the anticline, the reason being probably that the pits are in work, whilst they are less visited by collectors. As an instance of the mode of occurrence of fossils it may be mentioned that *Pholadomya deltoïdea*, Sow., was obtained in large numbers from a particular pit in Cornbrash, near Prattle Wood, although the species was not seen in any of the other pits visited during the day. Descending to "the Plain," a broad flat of Oxford Clay, the walk was continued across that formation (seen in a pond by the road-side) in a south-easterly direction to the hills forming the Corallian outcrop. The line of fault, previously referred to as bringing up the Great Oolite in the Islip inlier, runs almost along the line of this road, crossing it at the foot of the escarpment, and producing a difference of level in the feature-forming bands on either side of the road, which is particularly noticeable as the high ground is approached from the Plain. Several sections in the Corallian Beds were visited, showing slightly different structure to those at Shotover Hill, a good view of which was obtained from the top of the hill near Stanton St. John. Another instance of the peculiarly local occurrence of

fossils was met with in a pit on the right-hand side of the road, where *Echinobrissi* were picked up in handfuls. Descending towards Wheatley a fine section, just north-west of the village, shows clay at the bottom, with Corallian Beds on a higher level to the north. This clay, from its apparent stratigraphical position, ought to be Oxford Clay; its fossils, however, show it to be of Kimeridge age, the zone of *Ammonites biplex*, brought down into this position by the fault before referred to. Several characteristic Kimeridge fossils were found, and, in speaking thereon, the Director cautioned the party that the occurrence of *A. biplex* would not in itself establish the clay as of Kimeridge age, since that fossil had been recorded through the Corallian to the Oxford Clay. There was no doubt, however, as to the age of the clay in this section, as a whole assemblage of Kimeridge fossils had been found. From Wheatley Station the party took train to Oxford or Woodstock.

MONDAY, MAY 27TH.—The forenoon was spent, by those of the party who had previously arrived in the city, under the guidance of Mr. James Parker, F.G.S., who again earned the gratitude of Members by placing his vast stores of archæological and historical knowledge at their disposal.

At midday, having been considerably augmented from various quarters, the party proceeded by train to Charlbury, walking thence to the old ironstone workings at Fawler, where the following section is exposed :—

Chipping Norton Limestone. Clypeus Grit.	Inferior Oolite.
Upper Lias Clay, with Ammonite-band at base.	Upper Lias.
Marlstone-rock Bed, *A. spinatus* zone. Sands and calcareous sandstones, *A. margaritatus* zone. Shale, with ironstone-nodules, *A. capricornus* zone.	Middle Lias.

Needless to say heavy bags were made by collectors from this celebrated locality. Not so, however, at the next stopping place—

the equally celebrated slate workings at Stonesfield, where, in spite of large rewards offered, no vertebrates were disentombed, an extremely doubtful specimen, introduced to the notice of Members at some length by the President, being considered a forgery, probably the work of *Homo sapiens*, var. rude-*is*. From Stonesfield the road to the south-east was followed, and near Combe, in a wood, the Forest Marble, in its more typical condition, was seen. This formation takes its name from Wychwood Forest, a few miles to the west; it is a fissile limestone composed of comminuted shells, etc., the structure being well seen in weathered slabs, many of which were found. Proceeding south to the railway, in a cutting near Handborough Station, the Great Oolite was seen, and its fossil *Polyzoa*, collected. This formation is overlain by Forest Marble and Cornbrash, both of which were recognized on the slopes. In a quarry near Handborough Station the Cornbrash was again seen, and its fossils collected. This concluded the business of the day, the party proceeding to Woodstock through Blenheim Park.

Tuesday, May 28th.—This day was devoted to the time-honoured sections at Shotover. From Magdalen Bridge the party proceeded along the Cowley Road to a brick-pit in the Oxford Clay, yielding an abundance of large *Gryphæa dilatata*. On the plateau of Corallian Beds numerous quarries were visited, and attention drawn to the different conditions of the corals found in them. Whereas, on Saturday, at Wheatley, the beds seen consisted of a limestone composed of coral and other organic *débris*, evidently accumulated on a bank some way out at sea; here were found, in the first pits visited, corals in a more or less rolled condition, but still easily recognizable as corals; whilst further on, at Headington, so perfect was the condition in which they were found that one had no hesitation in saying that they had been preserved on the spot upon which they grew. In fact, the whole series was just what one would expect to find as the result of the action of a sea beating upon a coral shore. All the main features of the Shotover Section were seen, but they have been described so often that it is unnecessary to particularize them. At the conclusion of the day's proceedings a hearty vote of thanks was given to the Director, who, as a University Professor, had beaten the record by accompanying the party throughout the whole of the excursion.

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EXCURSION TO WALTON-ON-NAZE.

SATURDAY, JUNE 7TH, 1890.

(In conjunction with the Essex Field Club and the Ipswich Scientific Society.)

Director: W. WHITAKER, F.R.S.

(*Report by* THE PRESIDENT.)

The members of the three societies assembled at Walton at about 12.30, and strolled through the town, stopping on the way at the Tidal Mill. Mr. Whitaker said that this kind of mill was extremely rare in the South of England. Whether it was in active use he could not say, but as originally constructed, the water was imprisoned in a reservoir at high tide, and supplied motive power for the mill as it ran out at low tide. The use of the immense power of the tides would, he thought, soon become more general, and it was highly probable that these mills would come into use again for the purpose of working electrical machinery and lighting towns which were favourably situated.

The road then taken was along the breastwork or sea-wall, and on the base of the cliff (inadequately protected from the ravages of the sea by groynes of wood and concrete) to the cliff on the north. This cliff consists at first of London Clay, which extends out along the foreshore, and is capped above by Red Crag. The London Clay is jointed, almost unfossiliferous

(except for plant-remains in iron-pyrites), with cement-stones (septaria) and many small nodules of pyrites.

On arriving at the cliff containing the Red Crag the party descended to the level of that formation for the purpose of collecting its well-known shells a little eastward of Walton Town. The lower part of the cliff was seen to consist of London Clay, which, owing to the overlying beds being cut back by the action of springs at their base, afforded a means of examining the Red Crag which the existence of a perpendicular cliff would have prevented. Above the London Clay was seen the reddish sand, containing shells, known as the Red Crag. The shells were mostly reduced to fragments, a result only to be expected, as the Crag at Walton is much current-bedded. The Crag fossils are of two kinds, those derived from older formations, such as the London Clay and White Crag, and those more properly its own. From the London Clay are sharks-teeth and the vertebræ of fish, while from the White Crag have been derived many Polyzoa. A complete list of the fossils found in it appears in the Geological Survey Memoir on Sheet 48 S.E. The Crag rests on an uneven surface of London Clay, and Mr. Whitaker remarks that the latter sometimes rises through the lower beds of Crag. Mr. H. Stopes, F.G.S. (in 1874), noticed a thin bed of phosphatic nodules in certain places at the base. Above the Red Crag is "a bedded loamy deposit" which may be allied to the "Chillesford Beds" of Suffolk, and which is capped by fine gravel.* This gravel is considered by Professor Prestwich to be "Westleton Shingle." But as to this point the reader is referred to Professor Prestwich's paper on the Westleton Beds in the 'Quart. Journ. Geol. Soc.,' vol. xlvi (1890).

Descending the cliff, the geological collectors were enabled to obtain some fair bags of Crag fossils. Mr. J. W. Eagle having kindly given his permission for an exploration of the few remaining patches of the Crag. The damage done by the recent landslips was very evident in many places, and falls were seen to be still taking place almost daily.

Speaking of the possibility of coal being found in Essex, Mr. Whitaker pointed out that many years ago, in a deep boring at

* Mr. W. H. Dalton has lately suggested that the loam may be Post-Glacial ('Essex Naturalist,' Vol. iii, p. 224).

Harwich, a little to the north, Lower Carboniferous rocks were found at a depth of 1,029 feet. Similar evidences had been obtained from other borings in London, and as they had got so near, it seemed to him that, somewhere in the intermediate district, there was a very good chance of Coal-Measures being touched. The position was briefly this—at Harwich they had found rocks slightly older than the Coal-Measures, they knew that at Dover there were actual Coal-Measures, and many spots between these two points were favourable sites of exploration for coal. The only difficulty was that the Tertiary beds increased in thickness as they got further from these outlying limits, but as the rocks at Harwich were found at a depth of about 1,000 feet, and some collieries were 3,000 feet in depth, there was reason to hope that the coal would not be unworkable.

The botanists of the party explored the cliffs and the meadows inland, under the guidance of Mr. C. A. Wright, F.L.S., but nothing worthy of special note was found. The next day, on the sand-dunes west of Clacton, some interesting plants were observed, including *Convolvulus Soldanella*, *Arenaria peploides*, and *Eryngium maritimum*.

Tea was taken at Dorling's Hotel, when Mr. Holmes proposed a vote of thanks to Mr. Whitaker for his services as Director and to Mr. J. W. Eagle for his permission to examine the cliffs, remarking that, notwithstanding the recent erosions, a party of fifty could very seriously damage the cliffs and the few pieces of Red Crag that remained in Essex in a much shorter space of time than the elements could.

Some of the Members decided to visit Clacton, Mr. Whitaker again acting as geological guide. The "Royal Hotel" was the headquarters. At Great Clacton the party was interested in noticing that the walls of the originally Norman, but largely restored church, were mainly composed of nodules of septaria from the London Clay. Great Clacton is about 1½ miles northward of Clacton-on-Sea. At the latter place the chief objects of geological interest are the section of the cliff under Martello Tower No. 6, at the western end of the town, and the remains of a submerged forest, a little further westward. The cliff section is fully described and illustrated in the Geological Survey Memoir on Sheet 48 S.W. East of the Martello Tower

the cliff consists of London Clay, on which rests gravel, which Professor Prestwich is somewhat inclined to class as Westleton Shingle; above which, again, lies some irregularly-bedded loamy gravel. But as we approach the Martello Tower from the east the two beds of gravel just mentioned are seen to be separated by a thin bed of greenish-grey mottled clay, which gradually descends and thickens westward, and is seen to belong to a series of estuarine and fresh-water beds of Post-Glacial age, the lower members of which lie at the base of a cliff consisting of London Clay, and of the lower of the two gravel beds. Mr. Dalton remarks, in this memoir, "The presence of purely fresh-water beds below high-water mark, passing up into estuarine deposits on the top of the cliff (20 feet above high-water mark) indicates gradual submergence and subsequent re-elevation."

The submerged forest is only visible at low water, and consists of a blue clay with vegetable remains, about 18 inches thick, and lying on the London Clay. We saw many prostrate trunks, and, among others, the branch of a birch tree. Mr. Whitaker was of opinion that these trees had grown on some alluvial flat, which, owing to the inroads of the sea, combined with a slight subsidence of the area, had been brought to its present position and level; and Mr. Dalton remarks, in the memoir already mentioned, that "the existence of foundations on the verge of the tidal flat of St. Peter's Sands, seven miles W.S.W., seems to favour the theory of subsidence within the historic era, as at present alluvium is being deposited there."

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EXCURSION TO THE BAGSHOT COUNTRY BETWEEN ALDERSHOT AND BROOKWOOD.

SATURDAY, JUNE 14TH, 1890.

Directors: HORACE W. MONCKTON, F.G.S., and R. S. HERRIES, M.A., F.G.S.

(*Report by* THE DIRECTORS.)

The object of the excursion was two-fold, partly to visit some sections in the Upper Bagshot Sand, and secondly to study the gravels.

The Bagshot sections visited are marked and numbered in the sketch-map which accompanies a paper on the Upper Eocene, by Messrs. Gardner, Keeping, and Monckton ('Quart. Journ. Geol. Soc.,' Vol. xliv, p. 616), and the reference numbers are given in the following description.

The sections visited were:—Section 23—Close to Mitchet Lake, where the gravel is seen resting on Upper Bagshot Sand.

Section 21—The Tunnel Hill section, which is by far the best exposure of the Upper Bagshot Sands to be seen. A considerable collection of casts and impressions of shells was made here by the Directors in 1876-80, and 43 species have been determined, showing satisfactorily that the upper part of these sands are of Lower Barton age. A series of these fossils have been presented by one of the Directors to the Jermyn Street Museum.

Section 20—The gravel-pits near the old windmill, showing gravel resting on Upper Bagshot Sand.

Section 24—The rifle-range sections near North Camp station were seen at a distance.

From Tunnel Hill to the old windmill the party walked along the top of the Fox Hills, which forms a remarkably flat plateau, varying in altitude from 390 feet above O.D., at the southern end, to 376 feet near Tunnel Hill, and 357 feet at the northern end. It is capped by gravel, which was seen in section at the Tunnel Hill railway-cutting east of the tunnel, and also in a shallow pit near the windmill at the northern end. This gravel belongs to the Southern Drift of Professor Prestwich ('Quart. Journ. Geol. Soc.,' Vol. xlvi, Pl. 7, Fig. 2). Along the sides of the plateau,

terraces, and even sheets of gravel of a similar character were seen, and a series of pits were examined at the northern end of the Fox Hills, near the old windmill, at various levels, from the top to about 270 feet above O.D. The upper pits showed irregularly stratified gravel with beds of coarse dark-red or orange Sand, often hardened into "pan," resting on the Upper Bagshot Sand, and the lowest section showed 15 feet of roughly stratified gravel.

It was explained that similar gravel occurs close to the canal in the gorge which divides the Fox Hills from Chobham Ridges, and sections in a sheet of gravel of the same character, 228 to 280 feet above O.D., were visited near Mitchet Lake and in a new pit close to the North Camp Station. In every case the gravel was composed of subangular Chalk flints, with a small proportion of flint pebbles, and pieces of chert.

The Directors expressed an opinion that these lower gravels were probably old river gravels.

The party returned from North Camp Station to Waterloo.

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EXCURSION TO WOKINGHAM AND WELLINGTON COLLEGE.

21st June, 1890.

Director: Rev. A. Irving, D.Sc., F.G.S.

(*Report by* The Director.)

The Director met the Members who had travelled from London on their arrival at Wokingham Station at 2.37 p.m. He first drew their attention to the fact that the station stands on the London Clay, which was proved two or three winters ago in an excavation for a new siding close to the station. The station-yard is an excavation in the Bagshot Sands. Mr. Phillips' brick-yards close by, where the London Clay is extensively worked, were then visited and the working-up of the clay seen in full operation. The railway-cutting by St. Paul's Church was next examined. Here the Bagshot Sands are seen in open section on the south side of the bridge, some 15 feet being exposed of ferruginous rather loamy sands, becoming more loamy and somewhat contorted near the top of the section which had been planed down the same day. Immediately to the north of the bridge the London Clay is seen, with included Septaria, cropping out in the ditch and rising with a gradient of about 15° to the top of the cutting, the Bagshot Beds (which are horizontal in the section on the south side of the bridge) truncating off against the shelving denuded flank of the London Clay. The line of demarcation between the two formations is so definite that the eye can follow it even on the grassy slopes of the cutting by the difference of the verdure which covers them. On a previous occasion (Excursion, 1885) excavations were made by the railway employés exposing the two formations with a line of flint-pebbles resting on the surface of the London Clay. The unconformity here is seen to come out more conspicuously when the nature of the "soil" on the south side and of that on the west and north sides of the church is examined, the graves in the former being dug exclusively in the sands, while those on the north and west sides of the church are exclusively in the London Clay. The Director's own observations on this matter were confirmed by the testimony of Mr. Blake, the sexton, who met the party here by order of the Rector, the Rev. J. T. Brown, and traced the line of

demarcation at the surface across the churchyard. The unconformity here is a double one, beds not the lowest of the Bagshot resting on beds not the highest of the London Clay, from which probably something like 100 feet had been removed by denudation prior to the deposition of the Bagshot Sands at this place. For the argument in support of this view see the Director's paper 'On the Unconformity between the Bagshot Beds and the London Clay.'* The deep well at the Wokingham District Waterworks pumping-station, two-thirds of a mile south of this spot, commences in the London Clay at 170′ (O.D.) and passes through the whole of this formation as it is represented in the Wokingham district, through the Reading beds, then 50ft. or so into the Chalk.† It appears that here the water, which is too soft for Chalk water, is drained into a fissure in the Chalk, which serves as a reservoir, from the Reading Sands. It has been described by so high an authority as Professor Wanklyn as of "exquisite organic purity."

From St. Paul's churchyard the party proceeded by the Holt. Here, and in the cutting of the road which leads into the town, a strong clay is exposed, like to which nothing occurs in any of the deep well-sections on the north side of the Bagshot district below the basal clays of the Middle Bagshot (Nos. 9 and 10 of Dr. Irving's tabulation. See Wellington College well-section). The basal plane of these clays was clearly exposed about two years ago at the corner of the road in a fresh open section at 220′ (O.D.). The London Clay crops out about 15ft. below, and the sands between these two horizons are just the normal fine quartzose sands of the Wellington College well-section (No. 11). On these grounds the clays here are claimed for the middle group, and the attenuation of the Lower Sands thus becomes clear.‡ Walking through the town the party soon emerged upon an open field, where one of the secondary or terrace-gravels of the district is extensively worked for road-material. On reaching the Tangley cutting on the South-Western Railway the fine and current-bedded quartzose sands (No. 11) were seen up to about 10ft. above the line; these are capped by a distinctly laminated clay, here and there much contorted and puckered, with pockets of gravel driven into the hollows, the whole evidencing pronounced glacial action, *i.e.*, pre-

* 'Geol. Mag.,' Dec. 3, Vol. iii (1886).

† See 'Geol. Mag.,' Dec. 2, Vol. vii, pp. 422, 423.

‡ See 'Quart. Jour. Geol. Soc.,' Vol. xliii, "On the Physical History of the Bagshot Beds of the London Basin," by the Director, Fig. 1, p. 388.

bably the work of floating ice during the period of maximum glaciation of the old Thames Straits. The succession here is the same as near the Holt mentioned above. Here the Director gave a short exposition of the view put forward by the late Professor H. Carvill Lewis, of Philadelphia, and illustrated it by the glacial map of England which that promising and lamented young geologist presented to the British Association at Manchester in 1887.

Passing Tangley, where a recent excavation for a swimming bath exposed some 10 feet of the quartz-sand series (Nos. 11 and 12), another pit in the secondary gravels was noted. Walking for another mile and a half over the Lower Sands with no exposures the party reached Nine-mile Ride, where it is crossed by the new road from Wellington College to Wokingham. Here a halt was made to listen to some remarks of the Director on the sectional drawings he had made to illustrate the stratigraphy of the country as it can be read by direct correlation of the strata with those of the Wellington College well-section. A section, eight miles in length along Nine-mile Ride (running nearly east and west), showed the outcrop of the London Clay at the western end (where it is worked at 185′ O.D. in an open pit for brick-material). Three-quarters of a mile farther east the Bagshot clays crop out at about 210′ O.D., and at another three-quarters of a mile these clays are worked at California. These clays and the rest of the Middle Group above them were seen to rise gradually as they were traced eastwards, the top of the middle group being at 300′ O.D. at Cæsar's Camp (Easthampstead), at Red Lodge, and at Messrs. T. Lawrence and Sons' brickyards on the north side of Tower Hill.* Another section was shown giving the respective outcrops of the Bagshot Beds in a line due north of the Wellington College well and continued northwards to Buckhurst Hill, the clays at the base of which, exposed in the railway-cutting, were seen to be in direct stratigraphical alignment with the lower clays (Nos. 9 and 10) of the Middle Group. This puts the 50 feet or more of yellow sands above them in Buckhurst Hill† into the Upper Sands, and the lithological evidence points the same way.

A quarter of a mile further east one of the finest sections of

* These sections are all given in detail in the Director's recent paper in the 'Quart. Jour. Geol. Soc.,' Vol. xliv (1888), "On the Stratigraphy of the Bagshot Beds of the London Basin."

† See 'Quart. Jour. Geol. Soc.,' Vol. xliii, Fig. 2, p. 388.

Bagshot Beds seen in this part of the country was inspected, the pit having been preserved by Messrs. T. Lawrence and Sons, the proprietors, in view of this visit of the Association. Not only are the fine, current-bedded quartz sands (No. 11) seen in the pit-face with about eight feet of the basal clays of the Middle Group in a clean, fresh, vertical section above them, but the lithological differentiation of the two beds is brought out in the working of the pit, the Lower Sands being thrown out in one heap and used for "sanding the moulds" in the adjoining brickyard, while the material of the overlying bed is thrown into two other huge heaps and reserved for brick-material. Here, as on the southern outcrop of the Bagshot Beds, by Ash and Aldershot,* these two beds (Nos. 9 and 10) furnish most of the brick-material of the district. The same bed is worked at California as mentioned above. Irony concretions occur in it. It is generally strongly laminated, and has the same lithological character as the bed which is exposed at Bracknell Station, and is worked for moulding-bricks at Warfield, where it rests horizontally on the inclined strata of the London Clay.† The succession seen in this fine open section is the same as that described by the Director in numerous well-sections in this part of the country.‡ It has also been proved in a well-section north of Easthampstead Church.

Great as is the interest of the stratigraphical evidence afforded by this pit, the section is at least as interesting for the evidence of glaciation of this part of Berkshire. Between this and the glaciated sections in the Tangley cutting, described above, the present drainage of the country has cut down to the London Clay. This gives us a limit for the thickness of the Lower quartz sands, which cannot be much more (even when allowance is made for a slight dip) than 30ft. thick at Nine-mile Ride, since the basement line of the Middle Clays is at 230′ (O.D.) and the London Clay crops out in the valley at 200′ (O.D.). These 30ft. or so then represent 92ft. of the same sands in the Well-section at Wellington College, 1½ miles to the south. But, further, it is clear that this valley was excavated by ordinary processes of erosion down to

* See paper (with sections) by Lieut. H. G. Lyons, R.E., "On the Aldershot District," in 'Quart. Jour. Geol. Soc.,' Vol. xliii (August, 1887).

† See 'Quart. Jour. Geol. Soc.,' Vol. xliii, Section F, p. 386.

‡ *Ibid.*, p. 382, Section C; also 'Geol. Mag.,' Dec. 3, Vol. v, pp. 408, *et seq.*

something below 220′ (O.D.), before the period of maximum glaciation of this part of the country, if—as seems most probable—the contortions of the clays on both sides of this valley (220 O.D. at the Tangley-cutting, and 230′ to 240′ O.D. at the Nine-mile Ride) are due to bergs or floes of ice which floated in the waters that then filled the valley up to about this level. In the pit-faces at Nine-mile Ride the laminated clays are over-folded and plicated to an unusual degree. Great masses of secondary gravel (which occurs here and across Nine-mile Ride, on the south side of which it is extensively worked) are driven bodily into the clays, the foldings and flexures of which can be traced with the utmost precision, owing to the laminated structure of the clays. In one place we have evidence of a lateral thrust from the north, in another distinct evidence of the vertical pressure of a dead weight acting from above; the vertical force which drove the mass down into the clay being resolved laterally into forces which have nipped up the laminæ of the clay for a thickness of one to two feet, reproducing exactly the phenomenon of "creeps"* in disused coal-workings. This is seen less distinctly now than it was some weeks earlier, as, owing to the extension of the pit, the best section illustrating this point has gone for ever. Fortunately some excellent photographs of the section, as it then appeared, were secured at the time. This was on the pit-face facing north. (Fig. 1.) Those facing east and west are better preserved, though partly buried under pit *débris*; but photographs of these also are preserved. At first sight it is not easy to see how these huge masses of gravel were driven bodily into the clays as *solid* masses, as they evidently were. The true explanation is probably that they were in a frozen state at the time.†

The importance of the evidence of glaciation here is seen at once, when we reflect upon the fact that, in the absence of any very distinct evidence of glacial action at higher altitudes in this part of England, the present valley-system was probably excavated to a vertical extent of nearly 200ft. during the period of geologic time which elapsed between the deposition of the plateau-gravels, which cap the neighbouring hills at 400′ (O.D.), and the period

* See Lyell's 'Students' Elements,' p. 56, Fig. 59.

† Dr. Spencer, the State Geologist of Georgia, who has had great experience of glacial phenomena both in America and in Northern Norway, suggested this explanation on seeing the sections in April last, while on a visit to the Director.

of maximum glaciation of the old Thames Straits. All this was pointed out on the ground by the Director, and illustrated by a section drawn to scale from Bagshot Heath to Wokingham.



Fig. 1.—Messrs. Lawrence's Pit, near Nine-mile Ride, facing north.

The base of the clay is 230 O.D. in the pit-section by Nine-mile Ride: it is worked in the adjoining brickyard, where several millions of bricks are made from it annually: it is exposed in several small sections south of Nine-mile Ride, until it passes southwards under the green-earth series. In the line of road leading to Wellington College it is cut through by the cross-denudation of the country, so that the quartz-sands of No. 11 are exposed for about 100 yards: then, as the hill is ascended to the south, these clays

pass visibly in a number of sections under the green earthy sands. Above these occurs the clay-bed (No. 5 of the Wellington College well-section): then the ferruginous sands of No. 4; and upon these the pebble-bed (No. 3), about two feet thick, is seen cropping out at the base of the Upper Sands, in the road-cutting, at 264′ O.D, the same altitude as that at which it actually occurs in the well-section and (as proved by excavations) at intermediate points. Here, as usual, drift-materials, largely derived from the plateau-gravels, are strewn over the present surface of the country; but nothing of the kind has been found in the pebble-bed wherever it has been dug into at this place.

Unfortunately, rain had set in, and so the high road to the Hotel was preferred to a tramp through the heather along the strike of the Middle Beds, as they can be traced southwards from this spot to the cutting north of the railway-station. This fact, together with the lateness of the hour, caused fully half of the programme to be omitted.

This was the more unfortunate as the clay-pits which have been opened during the last two winters near the railway prove "up to the hilt" that the succession of the beds to the north of the station is that which is represented in the section published by the Director in the 'Journal of the Geological Society,' Vol. xliii, p. 388, Fig. 1.

After a substantial meal at the Wellington Hotel and some further remarks by the Director on some sectional diagrams displayed, together with a revised map of the district, the party took train at Wellington College Station for London, the interest of the afternoon's work having been acknowledged in a vote of thanks proposed by Mr. Leighton.

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EXCURSION TO LEITH HILL.

SATURDAY, JUNE 28TH, 1890.

Director: W. TOPLEY, F.R.S., ETC.

(*Report by the* EXCURSION SECRETARY.)

In spite of the threatening weather a considerable party met the Director at Holmwood Station. Once more was illustrated the truth of the adage, "Faint heart ne'er won fair maid," temerity being rewarded upon this occasion with a most enjoyable afternoon, the exquisite scenery of the district having special charms when viewed under a watery sky with fitful gleams of sunshine.

From the station the party proceeded west, and halted first near Anstiebury Camp (Hythe Beds), at a point on the road from which a good view is obtained of the Chalk escarpment to the north. After pointing out the more prominent features of the landscape, the Director called attention to the great width of the Lower Greensand outcrop in the neighbourhood of Leith Hill, as compared with the country to the east. This increased width is not due to any thickening of the beds, but to the east and west fault to the north of Leith Hill, and to the high dip of the beds on the east. (See Fig. 1, and also Geol. Surv. Map, Sheet 8). On the southern side of Leith Hill there is some slipped ground leaving bare patches, which are known to have been in existence for over 200 years. This slipped ground is at the same time a result from, and a proof of the existence of, a slight anticline coinciding with the summit of the hill.

A portion of the party then accompanied the Director into the wood to the left, and examined the remains of Anstiebury Camp, believed, from its circular form, to be British. Descending to the picturesque village of Coldharbour, the re-united party commenced

the ascent of Leith Hill (Hythe Beds). During a brief rest the Director called attention to the strong position of Anstiebury Camp, on a natural hill requiring little fortification. Proceeding with the ascent, a quarry in the Hythe Beds, to the right of the road, was examined. At Hythe the beds consist of limestones, but here are

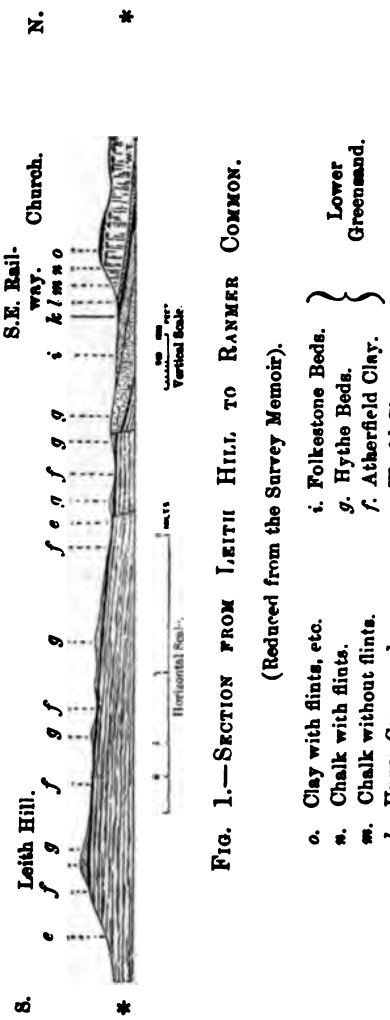


FIG. 1.—SECTION FROM LEITH HILL TO RANMER COMMON.

(Reduced from the Survey Memoir).

c. Clay with flints, etc.
n. Chalk with flints.
m. Chalk without flints.
l. Upper Greensand.
k. Gault.
i. Folkestone Beds. } Lower Greensand.
g. Hythe Beds. } Lower Greensand.
f. Atherfield Clay. } Lower Greensand.
e. Weald Clay.
* Sea Level.

sands and sandstones, with bands of chert, without lime or fossils; consequently the water is soft.

From the top of the tower on the summit of Leith Hill, the Director, after pointing out some of the chief features of the landscape, made some brief remarks on the general structure of the Weald, and more especially on that portion of the area immediately before the party. To the west Hindhead, and further round to the south the low wooded hills of Petworth, mark the outcrop of the Lower Greensand round the western end of the Wealden area. The flat in the foreground is entirely Weald Clay. The central beds of the upthrust, known as the Forest Ridge, and shown in the General Section across the Weald (Fig. 2), do not appear in this district; but their position and on-coming is indicated by the rising ground to the left of the plain. The Forest Ridge itself is seen in the hills on the south-east horizon. The line of the South Downs bounds the view to the south; whilst immediately in front Chanctonbury with its clump of trees shows the gorge to its left to be that of the Adur. The gorge of the Arun (to be visited by the Association on July 12th) is not seen from here, but its position is marked by the line of woods (Arundel Park) on the Chalk escarpment to the left of Petworth. Turning to the north the escarpment of the North Downs is before us, and, what is very remarkable, we see over the Chalk escarpment into the London Basin, a fact due, of course, to the superior height of Leith Hill (Lower Greensand escarpment), 965 feet O.D. In the foreground on the slope of the hill is a little valley running north, exposing Atherfield Clay at the bottom, where the Hythe Beds have been denuded. All the beds here dip north, and along the valley springs of beautiful water are thrown out on the surface of the clay. This led to the suggestion of this country as a possible source of water-supply for London. Having reached the subject of water, the Director called attention to the fact that Leith Hill, although situated on the northern escarpment of the Weald, formed part of its watershed. Starting from Fairlight, near Hastings, in the south-east, the watershed follows pretty closely the centre of the Forest Ridge, but upon reaching the flat country at its western end, the watershed turns suddenly north, across the Weald Clay to Leith Hill and Hambletree, then turning south to about its original latitude to pass out of the area to the north-west in about its normal direction. The cause of this deflection is the great thickness of the Weald Clay at Leith Hill. The dips here may also be due in great measure to this thickening of the beds.

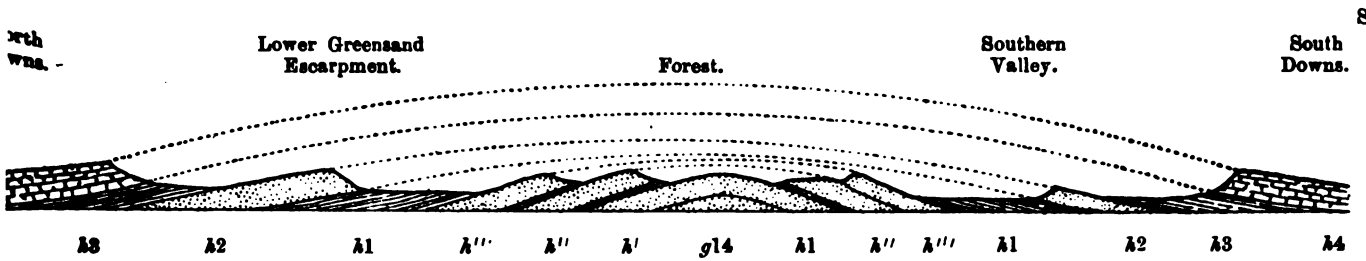


FIG. 2.—GENERAL SECTION ACROSS THE WEALD.

(Faint dotted lines indicate the strata removed by denudation.)

h 5.—Chalk.
h 4.—Upper Greensand.
h 3.—Gault.
h 2.—Lower Greensand.
h 1.—Weald Clay.
h'''.—Tunbridge Wells Sand.
h''.—Wadhurst Clay.
h'.—Ashdown Sand.
g 14—Purbeck Beds.

Whereas to the east the Weald Clay is some 500 feet thick, it is here known to be about 1,000 feet.

In consequence of the threatening weather, although the rain kept off the whole afternoon, it was deemed advisable to abandon the proposed visit to Wotton. The party therefore returned to Dorking along the valley to the north, referred to by the Director, noting the many springs on the way, and visiting a quarry in the Hythe Beds to the left of the road. Passing through the grounds of the "Rookery," a section resembling the sands of the Folkestone Beds was reached. The Sandgate Beds die out to the east near Buckland.

Tea at Dorking and a hearty vote of thanks to the Director closed the afternoon's proceedings.

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EXCURSION TO ARUNDEL.

SATURDAY, JULY 12TH.

Director: CLEMENT REID, F.L.S., F.G.S.

(*Report by* THE DIRECTOR.)

Leaving London Bridge at 10.25 a.m., the party reached Arundel Station about 12.15 p.m., and was there met by the Director.

A visit was first made to Arundel Castle and to the Fitzalan Chapel, by special permission of the Duke of Norfolk. Then, passing through Arundel Park, attention was drawn to the dry Chalk valleys and to their probable mode of origin. Continuing towards the northern edge of the Downs, the difference in contour between a true escarpment and an ancient sea-cliff was pointed out.

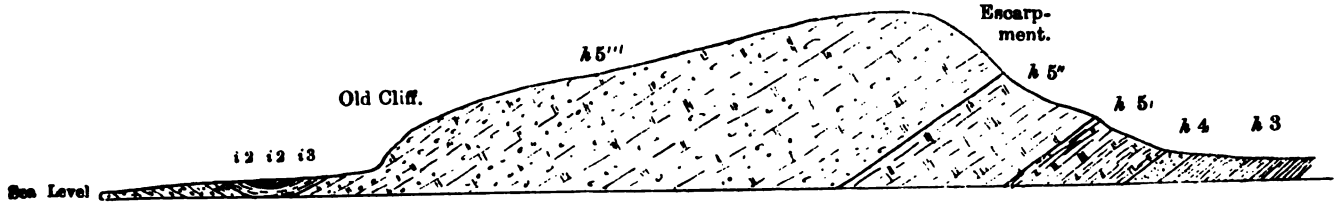


FIG. 1.—DIAGRAM-SECTION ACROSS THE SOUTH DOWNS.

i 3.—London Clay.
i 2.—Reading Beds.
A 5′′′.—Upper Chalk.
A 5″.—Middle Chalk (with Melbourn Rock at the base.)
A 5′.—Lower Chalk (Grey Chalk and Chalk Marl).
A 4.—Upper Greensand.
A 3.—Gault.

(See Fig. 1). Time would not allow of the excursion being extended as far as the escarpment, so a descent was made into the valley of the Arun, near Houghton. The rest of the way lay beneath the steep bluffs and hanging woods which border the Arun marshes. The study of the scenery and contours of the district being the special object of this excursion, no stop was made for the purpose of collecting fossils.

After tea at the Bridge Hotel, Arundel, a return train at 8.12 p.m. was taken to London.

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EXCURSION TO SHENLEY.

SATURDAY, JULY 19TH.

(In conjunction with the Hertfordshire Natural History Society.)

Director: UPFIELD GREEN, F.G.S.

(*Report by* THE DIRECTOR.)

In July, 1884, the Members of the Hertfordshire Natural History Society paid a visit to Newberries, to inspect a pit in which the Hertfordshire Pudding-stone was believed to occur *in situ*. After a lapse of six years the same spot was now again visited, and in anticipation of the event the pit had been further developed and opened up, by the kindness of Mr. H. Lubbock, the present owner of the estate. The bed previously seen was now found to consist of large and small blocks of conglomerate embedded in clay, overlying a stratum of black-coated pebbles of irregular size and much intermingled with sand and clay. The Director, referring to a plan and sections of the locality on a large

scale, pointed out that the spot on which they were then standing should be occupied by the upper beds of the Woolwich and Reading Series, and that the basement bed, if existing at all near that spot, should be at some distance further north. He, however, believed that the surface no longer consisted of these beds *in situ*, but that they had been re-arranged and intermixed with detritus of the London Clay washed down from the higher ground lying to the south by the stream which now flows at a much lower level. Referring to specimens he had brought with him, collected from various parts of this county and Buckinghamshire, he pointed out that only here and near North Mymms was the Pudding-stone found in immediate contiguity to the present outcrop of the Reading Beds, while elsewhere extending beyond Missenden in the west it was found embedded in Drift gravels, clay, or clay with flints. With regard to the conglomerate itself, great variation in the composition of the inclusions and the matrix was shown. Some specimens partook more of the nature of a breccia than a conglomerate, and while the inclusions in some, notably those under review, consisted almost entirely of pebbles of the Reading Beds, in others angular and subangular fragments of flint and chert, with rolled pebbles of chalk and clay silicified, were largely present. In some cases the silica cementing the sandy matrix had attacked and partially dissolved the pebbles. Passing on to the question as to the origin and mode of formation of these blocks, the Director expressed an opinion that they were of fluviatile origin and formed at the debouchure of streams flowing northward, which, draining the London Clay, cut through the Woolwich and Reading Beds, and deposited the detritus either in subterranean streams or in the bed of a Preglacial river, having a course parallel to and south of the Chalk escarpment. Two remaining representatives of these northern streams were the Mims stream, flowing from South Mims, which only after heavy rains flowed into the Colne, disappearing at other times, on reaching the Chalk, through various swallow-holes, and the Medburn, flowing from Elstree Reservoir also into the Colne, the swallow-holes near Radlett, through which the greater part of the stream formerly disappeared, having been plugged. The silica subsequently cementing these re-arranged materials he considered to have been derived from the decomposition of the soluble silicates of the felspathic constituents of the Glacial Drift. Time would not allow of a further development of his views on this occa-

sion, but he hoped to embody them at some future time in a detailed paper on the subject.

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EXCURSION TO THE MENDIP HILLS.

AUGUST 4TH TO 9TH, 1890.

Directors: Rev. H. H. WINWOOD, M.A., F.G.S., and HORACE B. B. WOODWARD, F.G.S.

(*Report by* THE DIRECTORS.)

Monday, August 4th.—Frome, Holwell, Vallis, Vobster, Luckington, and Mells (Director: Rev. H. H. WINWOOD).—A party of about 40 in number, most of whom had arrived in Frome on the previous Saturday, left the George Hotel on the morning of Monday, August 4th, in brakes and carriages, in the direction of Holwell and Nunney, for the purpose of visiting the many sections of abnormal Secondary deposits for which this particular neighbourhood is so celebrated. Passing through the suburb called the Butts—probably so named from the archery butts having been here erected in the days when bows and arrows were in use—their route traversed those flaggy and shelly limestones of the Lower Oolites, to which the name of Forest Marble has been given, and which form the building-stone of the greater part of the town of Frome. The maximum thickness of the clays, sands, grits, and limestones of this formation is here 130ft. The Chalk hills on the left, with the bold eminence of Cley Hill, near Warminster, and the Greensand slopes of the Longleat Woods, stood out clearly in the distance—the vallum forming the camp on Cley Hill being clearly defined. Skirting Marston Bigot (the seat of the Earl of Cork), a bulge in the wall indicates the care with which a very fine sycamore tree has been guarded, the seeds of which had been brought home from some distant land by a former noble proprietor. Turning off the main road at Nunney Catch, in the direction of Holwell, a narrow band of Fuller's Earth was crossed,

succeeded by the Inferior Oolite, which caps the hill leading down to the hamlet below. At a small roadside section on the right-hand side on the crest of the hill (distant about four miles from Frome) the first halt was made to examine the contact of the Secondary rocks with the Carboniferous Limestone. The Director (after a few preliminary remarks of welcome to the Association on their visit to the West, and the expression of his opinion that at the end of their week's Excursion they would agree with him that the geological phenomena which he had the honour of pointing out to them were second to none anywhere else in interest) briefly described the local peculiarities. They were standing, he said, on the S.E. end of the Mendip axis—a range of hills extending from Frome in a N.W. direction to Weston-super-Mare, and once most probably crossing the Channel to South Wales. The central nucleus consisted of Old Red Sandstone, with the Carboniferous Limestone dipping away on either side, so as to form a saddle-back or anticlinal. Though of comparatively insignificant height, ranging from 400 to 1,060ft., with a breadth varying from three to five miles, they have played a most important part in modifying the physical features of the district. Since their upheaval in post-Carboniferous times, a vast amount of denudation has taken place, and on their bevelled-off upturned edges the Secondary rocks had been laid down, thus presenting the most interesting examples of unconformability; and in nearly every instance where these rocks were found resting on the Palæozoic floor their normal lithological character had been much altered under such conditions as had yet to be explained. Many instances of this they would meet with in their rambles. The thickness of these Secondary beds, too, varied very much on either side of the Mendips. Immediately on their south side these formations, from the Inferior Oolite to the Triassic beds inclusive, have been estimated to attain a thickness of over 3,000ft., whereas on the north side they have been reduced to about 170ft. How can this be accounted for? The late Charles Moore, who, in his knowledge of the local geology was second to none, considered that these hills acted as an island barrier in former times, and were never entirely submerged, only admitting here and there certain incursions of the deeper seas, which washed their south flanks, but preventing them from penetrating northwards, and thus materially affecting their deposits, which, on that side, indicated much shallower water. Another feature to be noticed

was the great disturbance which the older beds had undergone, especially on the north side, where the strata of Carboniferous Limestone plunge down so deeply as to become in some cases vertical, and finally to be so over-folded at one or two points (notably Luckington and Vobster, places to be visited in the day's programme), as to overlie the true coal beds which have been worked beneath them. As the Members passed over the level ground in the morning, and looked across the apparently gradual slope between them and Cranmore tower, one of the highest points of the range, they little thought that the intervening ground was so much cut up as it is with lovely wooded combes. Some of the most interesting of these they would traverse to-day. Before visiting these, however, he wished to point out that at the place where they were standing —the "Marston Road Section"—was seen the most south-easterly exposure of the Carboniferous Limestone in this neighbourhood, and the first example of unconformability. Looking at the section before them (some 10ft. in depth to 90ft. in length) they might think that the rock was all of Carboniferous age, but a little use of the hammer would show them that such was not the case. The upper portion consisted of about 2ft. of Inferior Oolite, conglomeratic at the base, indicative of a shallow-water deposit, and succeeding this was a dense, pinkish-yellow and brown crystalline limestone of Liassic age, resting on a floor or base of Carboniferous Limestone. Hammers were busily at work, and several fossils obtained, amongst others from the upper beds *Rhynchonella spinosa*, characteristic of the Inferior Oolite, and from the lower beds *Terebratula punctata*, *Rhynchonella variabilis*, etc., etc. Before leaving the section, Mr. McMurtrie, Mr. Maurice Horner, Mrs. Fortescue Horner, of Mells Park, and the Misses Horner joined the party, and continued with them the rest of the day. The next point of interest was a now unworked quarry, on the right hand of the road leading to the hamlet, and on the east of the little stream that flows through the Nunney Valley. Here, from a rising knoll, the Director pointed out the peculiar projecting shoulders of chocolate-coloured and reddish-brown rock, which stood out from the west face of the quarry like buttresses. To one unacquainted with the peculiarities of the district, the rock before them might be taken for Carboniferous Limestone, but these were the so-called Liassic "dykes" of Charles Moore (Fig. 1), from the weathered sides and joints of which he had obtained a remarkable Liassic fauna.

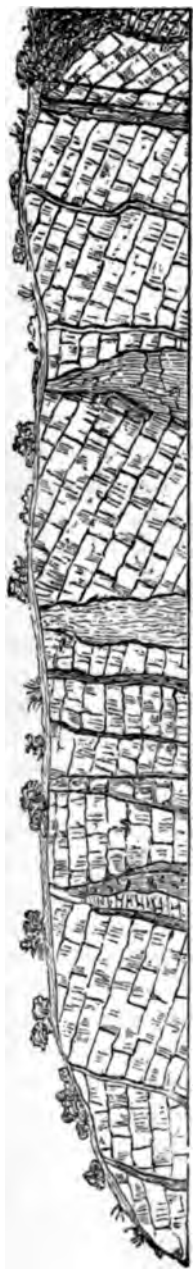


FIG. 1.—SECTION AT HOLWELL SHOWING LIASSIC VEINS IN MOUNTAIN LIMESTONE. (C. MOORE).
(From the 'Quart. Journ. Geol. Soc.,' by permission of the Council of the Geological Society.)

Being of a harder, more impracticable, and less valuable limestone, the quarry-men have left them standing, and worked back the more profitable beds on either side. These infillings, which had been proved to contain deposits of probably Triassic, certainly of Rhætic and Liassic age, were also coloured red with oxide of iron, and contained traces of galena. The thickening of these infillings at the base, and their gradual thinning out upwards to a mere crack, together with the Oolitic capping on the top, were noticeable features. The younger and more active of the party swarmed up the buttresses in search of univalves and other characteristic fossils, but without much success, their condition at the present time not being favourable for a good "find." Crossing the stream to the west side of the valley, the party visited the celebrated Microlestes quarry, whence Charles Moore obtained his harvest of Rhætic remains. The section has been so much altered of late years, and so worked back from the road, that the old fissure, with its peculiar greenish clay, has almost disappeared, and but few know where it existed. A yellowish vein, however, runs now parallel with the face of the quarry, whence many of the party succeeded in obtaining several teeth of *Acrodus* (*Lophodus*), *Saurichthys*, and *Hybodus*, and one specimen of *Sargodon tomicus*, together with vertebræ and fish-scales. On the opposite side of the road another section was visited, where the limestone had been worked back in the usual way, and the Secondary infillings left standing out on either hand. The floor of this quarry, dipping rapidly to the south,

yielded three or four very good specimens of *Phillipsia*. A question having been asked as to the horizon of the flaggy beds containing these trilobites, Professor Lloyd Morgan, at the request of the President, stated that the Carboniferous Limestone Series in the Avon section presented the following sub-divisions :—

	ft.
Upper Transition Beds (Upper Limestone Shales) ...	600
Upper or *Lithostrotion* Limestone (Middle Limestone of Mr. E. Wethered)	800
Middle Shales (*Mitcheldeania* Beds)	200
Gully Oolite	100
Lower or *Encrinital* Limestone (Black Rock) ...	550
Lower Transition Beds (Lower Limestone Shales) ...	320
	2,570

The Upper Limestone, he said, could generally be distinguished from the Lower Limestone by the presence of *Productus*, *Lithostrotion*, and *Cyathophyllum* in abundance, the Lower series giving encrinital stems and ossicles and *Spirifera*.

In the Mendips the Lower Transition Beds had approximately the same thickness as at Clifton; but the Lower Limestone was more than double the thickness (1,300 feet at Burrington Combe). He had not succeeded in getting a satisfactory measurement of the Upper Limestone, and believed that the condition of deposit of the Upper Transition Beds was peculiar in the Mendips. The quarry before them was in Upper Limestone.

At the top of the hill the brakes were remounted, and the Palæozoic ridge crossed to Nunney, where the Castle was visited, and a few minutes allowed to Mr. Parker for a short description of the structure. Built by Sir John Delamere about the year 1373 (he said), it was a transition between the military Norman keep and the fortified manor-house. The space on the ground floor was probably used for the storage of food for the household. The large room on the first floor was the dining-hall; the four towers at the corners fitted up for domestic offices, bedrooms, etc.; whilst the top of the Castle was no doubt used for military purposes.

Before crossing the moat which surrounds the Castle, the Director called attention to some large subangular blocks of grit, which lined the pathway leading to the rustic bridge across the stream. Some question had been raised as to their derivation, and

a suggestion made that they were Sarsen stones, but he thought there could be little doubt as to their being blocks of Millstone Grit, and evidences of the great denudation that had taken place around.

After a brief visit to the church and an inspection of the Perpendicular screen, and of the monuments on the north side erected to the Delamere family, the drive was resumed to Eggford bridges, passing through the grounds of Mr. Shore, and skirting the richly-wooded Whaltey Combe on the right. Just before the turn to the Mells Road, Mr. Horner pointed out in a field on the right hand the last cropping up of the Carboniferous Limestone in this direction through its covering of Fuller's Earth. The brakes being left at the entrance of the Vallis, the party walked to the first quarry, and, scattered about in picturesque groups in the shade, rested a while for the much-needed luncheon; whilst the amateur photographer of the party brought his camera into requisition. After luncheon the Director called their attention to a rusty-brown rock capping the fine exposure of Carboniferous Limestone at the south corner, and so filling up the inequalities of the Limestone floor as to make it extremely difficult to see where the junction takes place. Several characteristic Oolitic fossils from the tumbled blocks were obtained, *e.g*, *Lima pectiniformis*, *L. gibbosa*, *Ostrea*, *Echini*, etc. It was probably from this section that De la Beche obtained his specimen showing oysters of Oolitic age adhering to the Carboniferous Limestone, and bored by lithodomi.* In the centre of the quarry was a large vertical infilling of Secondary age, the top consisting of ochreous sand and the middle portion more solid, and indicating, as Mr. McMurtrie pointed out, a quiet sedimentary deposit of possibly Liassic age, the horizontal beds being plainly traced, layer by layer. Some good crystals of dog-tooth spar lined the fissure in several places. Moving on through the picturesque and wooded valley, the stream was crossed where it bifurcates, and a path on the left taken to the classical section of De la Beche, where the Inferior Oolite rests upon the upturned and bevelled-off edges of the Carboniferous Limestone (Fig. 2). Hand specimens of the junction of the lowest Oolitic bed with the former having been obtained with some difficulty, owing to the perpendicular face of the section, by a few of the more adventurous, the stream was recrossed in the direction of Hapsford Mill,

* 'Mem. Geol. Survey,' Vol. i, p. 289.

and 25 minutes allowed for the examination of the last section of striking unconformability in the Vallis. Standing under the welcome shade of the trees, the Director pointed out the peculiarities of this section, which he had often visited before, and more than once in company with Charles Moore, when it was being worked back for road-material. Since then it had been abandoned, and the distinctness of the various beds much obliterated, but they must trust to those who had described it under more fortunate conditions, and, without any probable, possible, shadow of doubt, they had before them the following section:—



FIG 2.—SECTION IN VALLIS, SHOWING INFERIOR OOLITE RESTING ON CARBONIFEROUS LIMESTONE. From a photograph by Mr. F. H. SMITH.

Carboniferous Limestone highly inclined at the base, succeeded by about 12ft. of Rhætic conglomerates, with partings of blue clay, and the whole capped by broken-up beds of Inferior Oolite.* At the N.E. corner, traces of White Lias limestone were visible. From the heaps of conglomerate blocks, composed chiefly of

* Moore, 'Quart. Journ. Geol. Soc.,' Vol. xxiii, p. 490.

Carboniferous Limestone with a mixture of siliceous pebbles, formerly piled upon the sides of the pathway, he had obtained the usual Rhætic fossils and teeth. Hammers had been busily at work, and several teeth with fish-scales found in the conglomerate in verification of the above statement. Leaving the Vallis, the route now lay through the villages of Elm and Mells, skirting Murdercombe on the left, and crossing over the Dolomitic Conglomerate to Upper Vobster. Several irregularities on the surface of the fields showed where trials had been made for coal. Standing on the outside of the fine mass of Carboniferous Limestone, here being worked by Mr. Batey for lime and road-material, the Director asked the party to notice the rapid dip of the beds southwards, now that they had crossed over to the north side of the anticlinal, and after distributing a few copies of a section (Fig. 3) from south to north (which, through the kindness of Mr. Batey, he was enabled to have printed), they were conducted by the latter through the tunnel, cut through grits and shales, with a thin perpendicular vein of coal at its further end, to the fine section of Limestone on the north side. Here Mr. McMurtrie, being on ground which might be called his own, opened out some admirable sections he had prepared, and explained the general features connected with these outliers of Carboniferous Limestone and their relation to the adjoining coal-field.

With the help of a map he pointed out that, when standing on the northern edge of the Mendip anticlinal and looking northwards, they had first an outcrop of Carboniferous Limestone, then a broad belt of Millstone Grit, and beyond this the principal basin of the Somerset Coal-Measures stretching away northwards, but that in the midst of these lay three isolated areas of Carboniferous Limestone, in one of which they were now met. The first and smallest of the three was the Tor Rock, situated on the edge of Mells Park, the second was the Upper Vobster Limestone, the largest of the three, which they were now examining, and the third was the Luckington Limestone, which they hoped to see by-and-bye.

He also submitted and described a section across the locality under consideration, pointing out that the section began with the Mendip Range, which was a true anticlinal, the central mass consisting of Old Red Sandstone, divided in places by dykes of igneous rock. From this central mass the Carboniferous Limestone dipped north and south at high angles, the beds on the northern side being in places vertical, if, indeed, they had not been

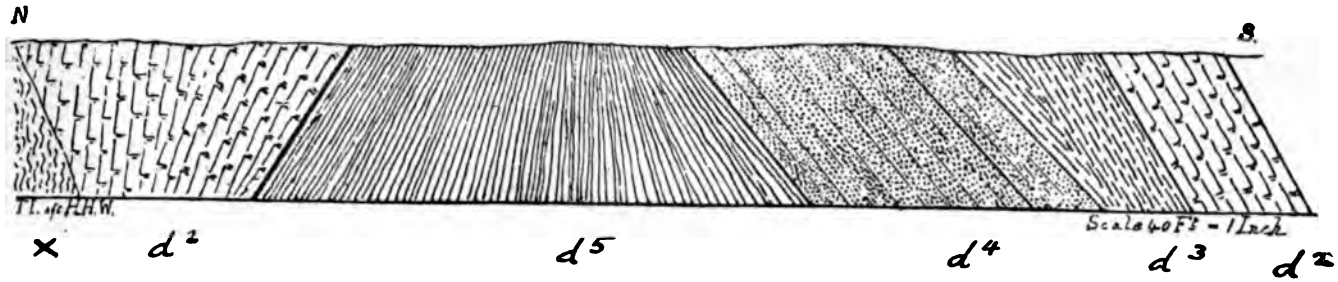


FIG. 3.—GENERAL SECTION ALONG TUNNEL AT VOBSTER, BY REV. H. H. WINWOOD.

d^3 Black Shales.
d^4 Millstone Grit
d^3 Upper Limestone Shales.
d^2 Carboniferous Limestone.
× Vein of Calc-spar.

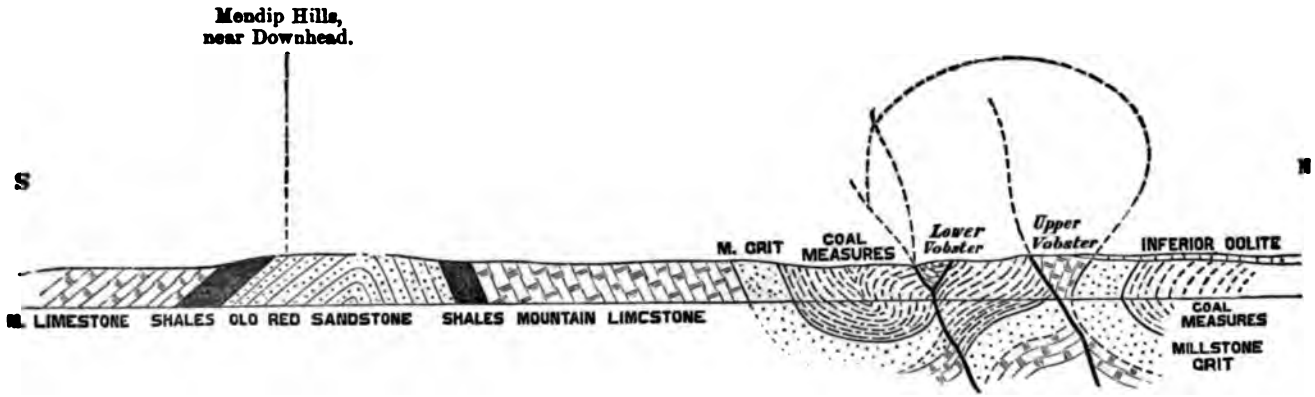


FIG. 4.—DIAGRAM-SECTION TO EXPLAIN THE OCCURRENCE OF MOUNTAIN LIMESTONE AT VOBSTER, BY H. B. WOODWARD.

From the 'Geological Magazine.' Scale about two inches to one mile.

folded over, the Millstone Grit following next with an unusual breadth of outcrop and other evidence of its having been folded over also, while the Coal-Measures had been completely overturned, carrying with them, as some believed, these isolated masses of Carboniferous Limestone which they were now considering.

These had been the subject of much curious speculation, and various theories had been brought forward to account for their abnormal position. First came De la Beche and his assistants on the Geological Survey, who attributed their origin to faults, and had shown these on the earlier geological maps and sections; but since their day extensive mining operations had been carried on in the immediate neighbourhood, and these, so far as he knew them, entirely negatived the fault theory, which was very improbable, seeing it would require an upthrow of 3,000 or 4,000 feet to account for its presence.

Next in importance, if not in point of time, came Mr. H. B. Woodward with a combined theory of fault and anticlinal, as shown in an enlarged diagram produced (Fig. 4), which he (Mr. McMurtrie) had been studying for a very long time without being able to understand. He had thought this theory had been disposed of long ago, but he saw from the papers connected with this Excursion that Mr. Woodward still stuck to it, and he (the speaker) could only admire him for the courage and tenacity with which he adhered to his convictions. There appeared to be no evidence, however, of either fault or anticlinal to support Mr. Woodward's theory, and a knowledge of the facts ascertained in the adjoining collieries would probably lead him to form a different opinion.

Next came the more generally-accepted theory—in which he (Mr. McMurtrie) entirely concurred—that, when the elevation of the Mendips took place, and the Coal-Measures were folded back upon themselves, these masses of Limestone had either been carried over with them, or had subsequently slipped down by the agency of a slide fault from the higher summits of the Mendips (then an elevated mountain range) into the positions which they now occupy (Fig. 5).

Of the main facts there was little room for doubt. The Mendips had undoubtedly been raised to a very high elevation, as he had endeavoured to show in the section; whilst the firmer beds of the lower division of Coal-Measures and the Pennant rocks above

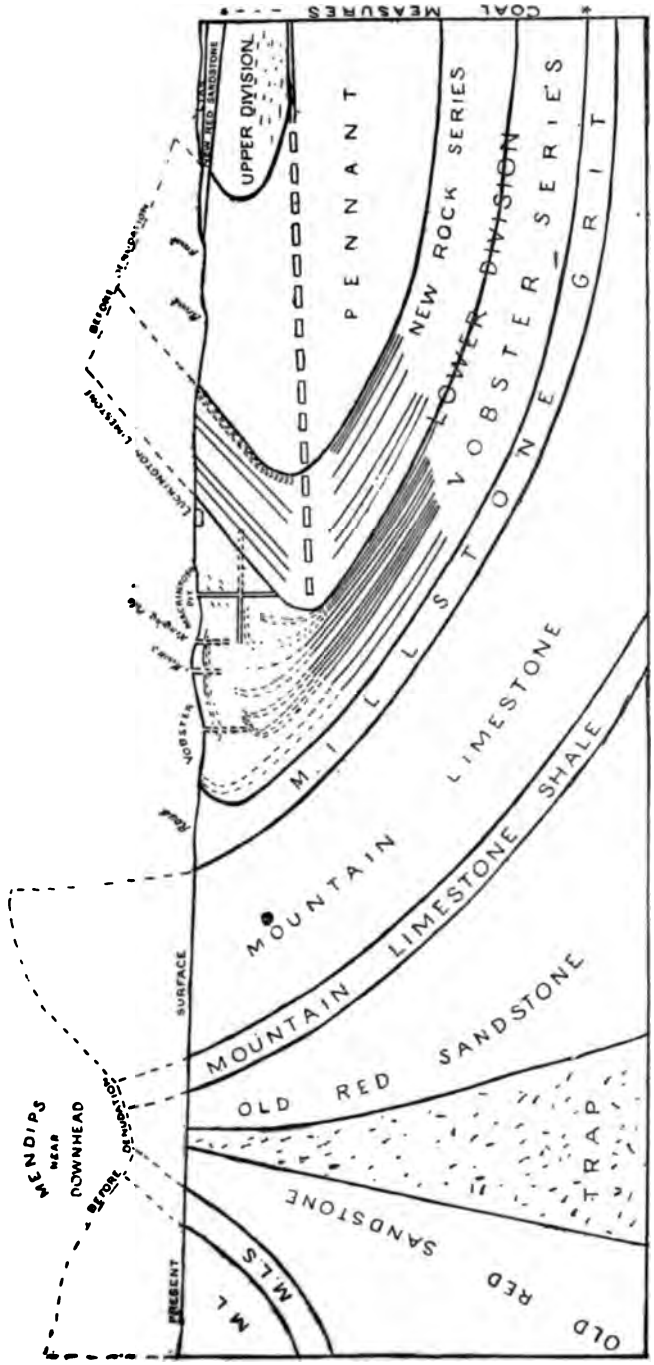


FIG. 5.—DIAGRAM OF THE FOLDING OF CARBONIFEROUS ROCKS IN THE MENDIPS AND AT VOBSTER, BY J. MCMURTRIE.

them had been overturned bodily, and that not for a trifling distance, but over a stretch of country four or five miles in length. The lateral pressure so produced had, in his opinion, thrust an upper slice of the Coal-Measures in the interior of the basin bodily forward, causing the veins to overlap each other to the extent of nearly 400 yards, so that the shafts there had passed through the same seams twice. The facts connected with this overlap had long been well known, the veins both above and below it having been fully proved; and he thought he was fully justified in attributing it to the cause already indicated, as shown by dotted lines on the section.

Between the Carboniferous Limestone and Millstone Grit of the Mendips and the harder strata of the Lower Coal-Measures lay a mass of tender shales containing the lowest veins, and when the overturn took place these shales seem to have crushed down like a wedge in the manner shown on the section, the beds having thus been disturbed and broken up to an extraordinary degree.

Mr. McMurtrie said the Somerset coal-field, on the southern margin of which they had met that day, was also interesting because it appeared to be in some respects a counterpart of the French and Belgian coal-fields, which he had the advantage of visiting a few years ago.* There was there on the south the same elevation of the older rocks pushed upwards and northwards by some great force, the Devonian, Silurian, and Cambrian being all present. This thrust had not apparently caused so great an overlap in the Coal-Measures there, but had expended itself more on the underlying rocks, the Carboniferous Limestone and Devonian having been thrust bodily northwards over the Coal-Measures, so that pits had been sunk there through both those formations before reaching coal. With so many disturbances on the Continent on the one hand and in the Somerset coal-field on the other, they could not expect it to be all plain sailing at Dover, of which they had lately heard so much.

Professor Lloyd Morgan said that although he was not prepared to accept the details of Mr. Woodward's fault theory, he believed that the presence of the Limestones was due to faulting. He was unable to understand Mr. McMurtrie's explanation, and hoped that Mr. McMurtrie would prepare explanatory diagrams

* See 'Proc. Bath Nat. Hist. and Antiq. Field Club,' 1890.

to illustrate the stages of the process by which he believed the Vobster and Luckington Limestones had reached their present position. While admitting that the grits described by Mr. Winwood were lithologically indistinguishable from Millstone Grit, he held that their association with shales and bands of limestone pointed to their correlation with the Upper Transition Beds of the Clifton Section, in which precisely similar grits occur.

Mr. McMurtrie said he was sorry Professor Lloyd Morgan disputed the identity of the Millstone Grit in the tunnel, but after comparing it with authentic specimens from the nearest outcrop he (the speaker) was bound to regard it as true Millstone Grit, and Mr. Batey, having compared it carefully with the same formation in Melcomb Wood, was unable to distinguish between them. He also regretted that he had been unable to make his section more clear to Professor Morgan, but in reply he pointed out that the Professor might as well dispute the overthrow of the Coal-Measures because the Millstone Grit was not lying above them as dispute the overthrow of the Limestone because the Millstone Grit was not beneath it; but of the fold over in the Coal-Measures there could be no doubt, and he thought there was equally little doubt that the Limestone had been overturned.

He endeavoured to show on the diagram the movements in the Coal-Measures which followed the elevation of the Mendips, and repeated his strong conviction that the Carboniferous Limestone outliers had in like manner been brought over into their present position, but he thought the agency of a slide fault or slip, first suggested by Mr. Seward Brice, Q.C., might have been partly instrumental in placing them in the position in which we now find them.

In conclusion, he said the recent workings at Newbury Colliery might possibly have thrown new light on the subject, and asked Mr. Batey to state his views.

Mr. Batey said he so far agreed with Mr. McMurtrie that the grit met with in the tunnel was true Millstone Grit, of which he had not the slightest doubt; and he also agreed with him in disputing the correctness of Mr. Woodward's section, which, like the previous speakers, he had failed to understand. But although at one time he (Mr. Batey) had been opposed to the fault theory and in favour of that long held by Mr. McMurtrie and

others, he was now rather inclined to go back to the fault theory. He did not think they had any evidence that the workings of the Newbury pit had been under the Vobster Limestone, nor that the Mackintosh pit-workings had been under the Luckington Limestone, which he thought was cut off to the west of Black lane by a fault lying parallel with the road, the outline of the Limestone as defined in the Ordnance Map, Sanders's map, and Mr. McMurtrie's diagram being alike wrong. He said, however, that if the Luckington Limestone extended to the west of the Black lane as shown in these maps, then the Mackintosh workings had been under it, and that it would be a strong point in favour of Mr. McMurtrie's theory. Mr. Batey further said that having worked the Coal-Measures from Newbury Colliery some distance northwards and from Kilmersdon Colliery some distance southwards, he had formed a theory of his own on this subject which he would reserve for the present.

In reply, Mr. McMurtrie pointed out that he had embodied in his diagram and section all the facts he had got from Mr Batey at an earlier time; and, if the Newbury workings had not been under the Vobster Limestone, the workings of two older pits had, he was informed, penetrated so far beneath it from opposite sides that the men could hear each other at work. As regards the Luckington Limestone, he hoped to show them presently that it extended far to the west of Black lane, as shown on the various maps.

After this somewhat animated discussion upon a subject which still affords plenty of scope for diversity of opinion, the next point visited was the section at Luckington, about one mile distant, where the Carboniferous Limestone is again exposed, and on which rest unconformably the black Rhætic shales, with patches of the Bone-bed at the base, succeeded by clays and shales representing the White Lias. These clays, formerly considered to be Coal-Measures, have recently been proved to belong to the Rhætics, thus showing their further extension south in the direction of the Mendips.*

After a few remarks from the Director, descriptive of the section, Mr. McMurtrie subsequently showed Mr. Batey certain outcrops of the Limestone around the Luckington farmhouse,

* H. H. Winwood, "On a Rhætic Section at Luckington." 'Proc. Bath Nat. Hist. and Antiq. Field Club,' 1890.

and in an old quarry in the western extremity of the field adjoining, which Mr. Batey then admitted to be an established fact, and as it proved the Mackintosh pit-workings to be beneath the Limestone, it was a strong point in favour of the overthrow theory.

The party mounted the brakes and returned to Frome through Soho, and, skirting Melcomb Wood, by the courteous permission of Mrs. Fortescue Horner drove through Mells Park, second to none for the beauty of its old oaks, passed out through the grove of beech trees, and were most hospitably entertained by the Misses Horner and Mr. Maurice Horner at the Rectory, where a refreshing cup of tea proved most acceptable. A short visit was afterwards paid to the old Manor House, formerly occupied by an Abbot of Glastonbury, and also to the Church and the beautifully kept churchyard, and Frome was finally reached at 7.15 p.m.

Tuesday, August 5th.—Cranmore, Doulting, and Shepton Mallet (Director: Rev. H. H. Winwood).—Before leaving Frome a visit was paid to the well-known ornamental brass works of Messrs. Singer, and the 11.38 train then taken for West Cranmore. The party here, increased by the addition of Mr. John Phillis and two or three others, drove thence to the well-known Inferior Oolite quarries at Doulting. The first one visited was close to the Great Western Railway, just where the road crosses the line, and is called "Brambleditch." A few minutes having been devoted to luncheon, the Director led the way to the top of the *débris* enclosing the quarry, whence a good view of the surrounding country could be seen. They were still, he said, in view of the Mendip ridge, the tower of East Cranmore, their landmark of the preceding day, being still visible in front of them. They were standing on the Inferior Oolite, which yesterday they had seen very imperfectly developed, with a depth of some 5ft. or 10ft. at the utmost, and resting on the upturned beds of Carboniferous Limestone; but here these beds were of much greater depth, as they could see in the railway-cutting beneath them, which exposes a section from the Midford Sands to the Fuller's Earth above. The Fuller's Earth is seen as a reddish-brown clay, filling the irregularities of the beds below, and, according to Mr. H. B. Woodward, there is a thickness of some 55ft. of Oolitic and Sandy Limestone, succeeded at the base by an unproved thickness of Midford

Sands, much obscured now by talus. A fault runs nearly parallel with the line, bringing the Fuller's Earth and rock in contact with the lower beds on the north and south. The beds in the quarry beneath them were the lower beds of the Inferior Oolite, a yellowish-brown, siliceous, calcareous and slightly oolitic stone much used in building. Fossils are very scarce in the lower beds, but he wished here to introduce them to Mr. John Phillis, of Shepton Mallet, whom they were much pleased to see amongst them, a man who had laboured hard at local geology, and by whose researches a fine collection of fossils had been obtained from these sections, which they would have an opportunity of inspecting at the close of the day. The following list of his finds had been put into his (the Director's) hands by Mr. Woodward:—*Terebratula globata*, *T. sphæroidalis*, *T. morieri*, *Rhynchonella spinosa*, *Waldheimia* (near to) *cardium*, and *Natica bajocensis*,* all belonging to the *Ammonites parkinsoni* zone.

With regard to *Terebratula morieri*, a very rare brachiopod, this species was first found in this country by Mr. J. F. Walker, at Bradford Abbas,† and the credit is due to Mr. Phillis of having obtained it from Doulting, the only other locality known in this country. After these remarks the refuse heaps were diligently searched, and many fossils found, amongst them the characteristic *Rhynchonella spinosa*; but it was noted that most, if not all, were derived from the rubbly, much-broken-up beds capping the more solid building beds below. Just above the latter, the horizon of the *Nautili*, *Ammonites*, *Trigonia* and *Pholadomya*, etc., were pointed out. A fine joint-plane running through the backface of the quarry, met by other joints at right angles, well illustrated the process whereby the large blocks were readily extracted.

Mounting the brakes the drive was continued back, past the fine Tithe Barn and through Doulting, to Mr. Trask's quarry at Cheylinch, about a quarter of a mile north of the village, passing on the left hand an old quarry called St. Andrews, whence the building materials for a great portion of Wells Cathedral and Glastonbury Abbey are said to have been obtained. At Cheylinch, Mr. Blake, the foreman, conducted the party into a newly-opened quarry on the left of the road,

* The species were identified by Mr. E. T. Newton.

† 'Geol. Mag.,' 1878, p. 552.

showed them how the stone was quarried, and explained the peculiar markings called "jaddings" and "patchings." The section here showed: Top (head), 4ft. to 5ft.; Soft Bed ("cake bed"), 2ft. 6in.; Rag Bed, 2ft.; "Weather Bed," good working stone, 15ft. The latter, composed of a brown, sandy calcareous, non-oolitic stone, was won much nearer the surface here than in the former section visited. Proceeding past Broadpool on to the Mendip anticlinal, the Inferior Oolite was left, and a halt made at a fine exposure of Carboniferous Limestone, called Waterlip, or Waterleap. The beds dip here rapidly to the south, and are being actively worked for road-metal. Hence comes the so-called "Mendip granite," a name which might be seen on the railway trucks throughout the line,

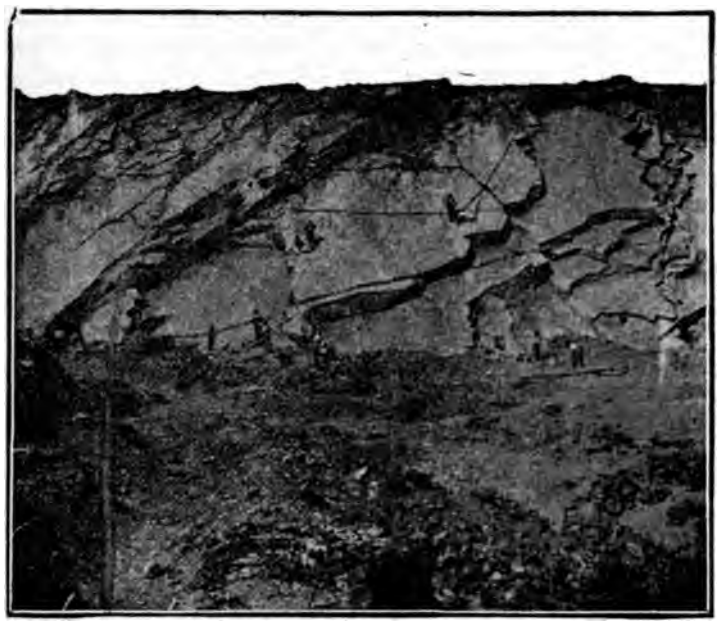


FIG. 6.—WATERLIP QUARRY. FROM A PHOTOGRAPH BY J. D. HARDY.

but which ought most certainly to be erased therefrom now the schoolmaster is said to be abroad, and is supposed to know at least the A.B.C. of geology. Mr. Phillis stated that the Inferior Oolite cropped up close to the foot of the quarry. After a photographic shot at the quarry and the workmen (Fig. 6), who seemed

somewhat surprised at the operation, the drive was continued up and over the Mendips to the great exposure of eruptive rock near Stoke Lane, called Moon's Hill quarry. After a few words from the Director, explanatory of the discovery of this rock by Charles Moore, when it only appeared as weather-worn bosses, cropping up here and there above the grass, though it had since been worked out by a company into the fine section before them, Professor Lloyd Morgan was called upon to describe the character of the rock itself. The Professor regretted that a more experienced petrologist was not present. He had only examined one section. In it there was orthoclase felspar and perhaps plagioclase, specks of magnetite, and a devitrified matrix, which might be felsitic, with ghosts of augite or hornblende crystals. There was also a good deal of a green mineral, the so-called viridite, probably a secondary product of the alteration of augitic or similar mineral. Mr. Rutley described the rock as a pitchstone porphyry, or porphyritic pitchstone.* The porphyritic structure was microscopic. The Professor was not prepared to suggest any other name in place of that given by so able a petrologist as Mr. Rutley, but he thought that the rock might be re-examined with advantage.†

Some specimens having been taken for examination, the party returned over the hill to Long Cross, and then followed the ridgeway in the direction of Shepton Mallet, stopping on the way to see a "gravel" pit near Beacon Hill, on the left hand side of the road, which here runs upon the Old Red. The section

* 'Geol. E. Somerset' (Geol. Survey), p. 208.

† Mr. Frederick Chapman has kindly forwarded the following note on specimens collected in this quarry:—The Trap (C. Moore, 'Quart. Journ. Geol. Soc.,' Vol. xxiii, 1867, p. 451; H. B. Woodward, 'Geol. Engl. and Wales,' 1887, p. 575) is of a dark purple colour, with traces of green; fine-grained in texture, and over the surface are disposed crystals of porphyritic felspar and hornblende. A section of the rock shows a ground-mass of plagioclase crystals of decided fluidal character. In a devitrified glass magnetite and hæmatite are also present in small particles. The porphyritic crystals are of plagioclase; hornblende, orthoclase, pyroxene in smaller crystals, and epidote. The felspars contain glass inclusions, and many are beautifully zoned. There are also alterations of hornblende, etc., into chlorite and kaolinized felspars. The volcanic breccia presents an ordinary appearance of brown and green alteration patches with a close-grained matrix. Among the included fragments are pieces of limestone, a vitreous rock crowded with microliths, porphyrite, and a devitrified pitchstone. This rock appears to be similar to the breccia from Wrington Warren.

consists of some four or five feet of pebbles of white vein-quartz, Old Red sandstone and white quartzite, a large pebble of the latter, four inches long by two and a half thick, having been picked up. Entirely a local gravel, it was probably weathered out *in situ*, the jointing in the beds bearing out this view, as was pointed out by Professor Lloyd Morgan, who also added that a similar gravelly conglomerate was found at Charlton, near Portbury, in the Old Red Sandstone.* Resuming the drive, a small quarry at Downside, on the left before passing the railway viaduct, was entered, and the Director said the rock here was of singular interest. They would hardly believe at first sight that the white calcareous granular beds before them belonged to the horizon of the generally blue-coloured and dense Lower Lias, but such was the fact. Clearly identical, lithologically, with the Sutton stone of South Wales, it assumes this altered condition wherever it is in close proximity to the old Palæozoic floor, and, as they see, is most highly fossiliferous. Some of the beds contain pebbles of chert and a blue Lydian-looking stone, indicating a shallow-water deposit and an old sea margin. Several good specimens of *Pecten pollux*, *Cardinia*, *Ostrea liassica*, *O. arietis (multicostata)*, etc., were gathered. The last quarry visited was that close to the railway station at Charlton. Here the Lower Lias assumes its normal character of layer upon layer of blue stone, with intercalated bands of yellow clay. Large Ammonites, some with their outer whorl smooth, *A. bucklandi*, *A. conybeari*, and *A. raricostatus*, *Nautilus striatus*, *Lima gigantea*, *Pinna*, *Gryphæa incurva*, and other fossils peculiar to this horizon were bagged, and the party returned to Shepton Mallet for the much-needed cup of tea. They then visited Mr. Phillis' admirable collection of local fossils at the Town Hall, where the rare and fine specimen of *Terebratula morieri* was examined. The Members duly acknowledged his geological labours, and then drove through Croscombe to the Swan Hotel, at Wells.

Wednesday, August 6th.—Priddy, Harptree Hill, Ebbor, and Wookey (Director: H. B. Woodward).—After breakfast, most Members proceeded to Wells Cathedral, where Mr. J. Parker and Mr. R. J. Manning expounded the leading features in its architecture, and dwelt at some length upon its historical asso-

* See also 'Geol. E. Somerset' (Geol. Survey), pp. 15, 162.

ciations. The cathedral is pleasantly situated, and it is said to present the finest outline of all those in England. Built for the most part of Doulting Stone (Inferior Oolite), its construction was commenced about the year 1190, so that portions of the choir, the western front, nave, and transept are in the Early English style; other portions of the choir, the lady chapel, chapter-house, and central tower, in the Decorated style; while the cloisters and western towers are Perpendicular. In the restoration of the west front, carried out a few years ago, the decayed columns of Blue Lias, which had supported canopies over the many statues, were replaced by columns of Kilkenny marble (Carboniferous Limestone). This new stone appears subject to a dull grey efflorescence, which gives the columns the aspect of large slate-pencils. Time did not allow of a visit to the Bishop's Palace (a fortified building of the 13th century), whose moat is fed by the springs to which the city owes its name. The principal of these is St. Andrew's Well. Like the waters of Wookey Hole, they originate on Mendip, diving underground in swallet-holes at the junction of the Lower Limestone Shales and Carboniferous Limestone, and re-appearing at the surface at Wells, through a weak point in the New Red Marls, there overlaid by valley gravel.

The Members now returned to the Swan Hotel, where a brake and two waggonettes awaited the party. Soon after ten o'clock a start was made along the Bath road, and then by the narrow and hilly road that leads to Priddy. After traversing this road for a short distance, passing small exposures of Dolomitic Conglomerate, a halt was made near East Milton, and the Members walked up a lane bordered by thick bushes and trees, and deeply excavated in the rocks. In the cutting an ascending series was visible from the New Red or Keuper Marls, through the Rhætic Beds to the Lower Lias; and to this attention had been directed in 1866 by the Rev. P. B. Brodie.* The section was of especial interest, on the present occasion, as showing these strata in proximity to the older rocks of the Mendips and yet maintaining their ordinary characters, the Lower Lias here being thus different from the white granular limestones seen on the previous day to the north of Shepton Mallet, and from the cherty beds on Harptree

* 'Quart. Journ. Geol. Soc.,' Vol. xxii, p. 93.

Hill, about to be visited. Towards the lower part of the section there was a fault bringing the Red Marls abruptly against the Lower Rhætic Beds. These latter, in ascending order, comprised about 13ft. of Grey Marls, in which some fish-remains had been obtained; about 9ft. of Black Shales, that yielded *Avicula contorta*, *Cardium rhæticum*, etc.; and about 12ft. of White Lias. The junction with the Lower Lias is here not so clearly defined as in many other localities, for the lowest beds of this formation include layers of pale-grey earthy limestone that much resemble White Lias, and appear to constitute passage-beds from one formation to the other.

After driving past East Milton, across a tract of Lower Lias, most of the Members walked up the steep hill that led to the top of Mendip. Sections of the Lower Limestone Shales, comprising shales with bands of limestone, were seen by the roadside, at the foot of the ascent, in places in a highly inclined position, partly owing to the effect of slips. The shales, which partially encircle the Old Red Sandstone of Pen Hill, plunge into and across the deep valley to the west of the road, and they are surmounted by a gently undulating mass of Carboniferous Limestone that here forms a prominent and picturesque "scar."

A short halt was made on the summit of the hill, where the Director pointed out the leading features (Fig. 7). The plateau of Mendip stretched far away to the east and west, formed mainly of Carboniferous Limestone, which here has a general inclination towards the south. The more conspicuous dome-like elevations of North Hill, Priddy, to the north; of Black Down to the north-west; and of Pen Hill to the south, were formed of the Old Red Sandstone, fringed (except where faulted) by the Lower Limestone Shales. Quarries were to be seen here and there in the Carboniferous Limestone, where the beds have been worked for road-metal, for building walls, and for lime-burning; and some fossils had been obtained in this area, including *Bellerophon apertus*, *Euomphalus tabulatus*, *Pleurotomaria*, *Productus semireticulatus*, *Strophomena rhomboidalis*, var. *analoga*, *Orthis resupinata*, *Streptorhynchus crenistria*, *Actinocrinus*, *Michelinia favosa*, etc.

This plateau of Mendip was, in fact, a plain of denudation, on the surface of which patches of Dolomitic Conglomerate,

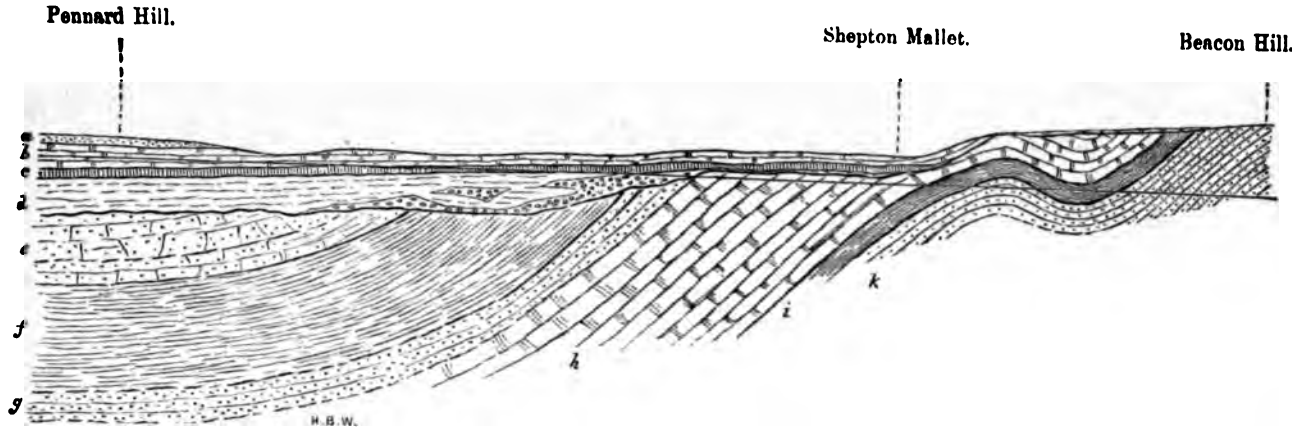


FIG. 7.—DIAGRAM-SECTION BY H. B. WOODWARD TO SHOW THE PROBABLE OCCURRENCE OF THE COAL-MEASURES TO THE SOUTH OF THE MENDIPS.

(The Section is taken along the Fosse Road.)

(From the 'Geology of East Somerset.')

Horizontal Scale = one inch to one mile.

Vertical scale = one inch to 2,400 feet.

a. Middle Lias.
b. Lower Lias.
c. Penarth Beds.
d. Red Marl and Dolomitic Conglomerate.
e. Pennant Grit.
f. Lower Coal-Measures.
g. Millstone Grit.
h. Mountain Limestone.
i. Lower Limestone Shale.
k. Old Red Sandstone.

Rhætic Beds, and Lower Lias occurred in places. Over this area, in early historic times, there stretched the Forest of Mendip, a tract of wild and partially-wooded land, that remained, for the most part, unenclosed until the middle of the last century. Traversing the Mendips a little further north was the Roman road from Old Sarum to Brean Down, and here and there Romano-British Camps were to be found, as at Masberry Castle to the south-east and Dolberry far to the north-west. Near at hand were the Eight and Nine Barrows of North Hill, and the curious circles of earth and stone met with in the same neighbourhood of Priddy.

The district between Priddy and Chewton Mendip was of interest as being one of the tracts from which, since ancient British and Roman times, ores of lead and calamine, as well as ochres, have been obtained from the Carboniferous Limestone and Dolomitic Conglomerate. Lead-ore was extensively worked in Roman times, and many interesting remains of this period have been obtained here and elsewhere, especially at Charter House, between Priddy and Blagdon, where a Roman smelting-mill was discovered.* Galena was the chief ore obtained, and it has been worked at intervals, together with calamine (carbonate of zinc), until about the close of last century. In the time of Edward IV. there were established certain "Laws and Orders of the Mendip Miners," which contain interesting clauses connected with the working of the ores.† The extent of the old workings is shown by the "hills and hollows" that occur over the surface of the ground to the east of North Hill and in other places. The shafts were sunk to depths of six or twelve fathoms, and but rarely to twenty or thirty fathoms. The ores were sometimes found in regular courses or grooves, whence the old miners were known as "groovers;" and these veins were found especially in the Carboniferous Limestone, and sometimes in the Dolomitic Conglomerate. At other times the ores occurred in large masses or hulks lying horizontally; in these cases in the Dolomitic Conglomerate. Particular accounts of the methods of working have been published by Giles Pooley and others.‡

* Rev. Preb. Scarth, 'Proc. Bath Nat. Hist. and Antiq. Field Club,' Vol. iii, p. 334.

† John Billingsley, 'General View of the Agriculture of Somerset,' 1797, p. 23.

‡ *See H. B. W.*, "Geol. East Somerset" ('Geol. Survey'), p. 167.

Billingsley remarked that the general method of discovering the situation and direction of the mineral veins was by the help of the Divining Rod, vulgarly called "josing." He adds that "most rational people, however, give but little credit to it, and consider the whole as a *trick*." *

Continuing their journey across the Mendips the Members now arrived at the St. Cuthbert's Lead Works, where they were received by the Manager, Mr. Thomas Willcox, who most kindly explained the means adopted for procuring the metal.

For many years no fresh material has been obtained from the rocks, lead being procured in sufficient quantities from the slags and slimes left by the old workers. Large accumulations of this kind have been found here and there at Stoke Hill, near Priddy, Charter House, East Harptree, and in the Tar Valley, near Chewton Mendip. In all cases the deposits are found on or near areas of Lower Limestone Shales, as in such situations water was held up in sufficient quantity for the purpose of washing the material that had been brought from the mines. Much of the refuse left by the workers dates back to Roman times, but that a good deal is of much later date is shown by the occurrence of early forms of tobacco-pipes. Mr. Willcox pointed out the various processes of washing and buddling or

* In the course of the evening (after dinner) the Director exhibited a Divining Rod, formed of a hazel-twig that had been cut for him by a Diviner at Chewton Mendip in 1872.* Referring to an interesting article on the subject, published by the United States Geological Survey,† he remarked that the application of the Rod dated from a very early period, and had been used to divine character and for various purposes, as well as in the search after mineral treasures and water. It was very generally admitted that the Rod itself possessed no powers, though it was thought that, being held in a position that somewhat strained the muscles, it might assist the individual in coming to a decision when he wanted to make up his mind. Further, it was quite possible, in the case of a search after underground flows of water, that a slight chilliness or humidity in the atmosphere might affect some organizations sufficiently to enable the Diviners, almost unconsciously, to arrive at a decision that water would be found at certain spots. This idea, expressed by Mr. R. W. Raymond, had also been entertained by J. G. Swindell.‡

The subject led to an animated discussion, in which both sides of it received supporters, and the excitement only abated after an adjournment to the smoking-room.

* 'Geol. Mag.,' 1872, p. 528.

† R. W. Raymond in "Mineral Resources of the United States," 'U.S. Geol. Survey,' 1883, pp. 610-626.

‡ 'Wells and Well-sinking,' by J. G. Swindell and G. R. Burnell, 1883, p. 27.

sifting the materials. The fine silty material or slime, when calcined, yields about 5 per cent. of lead, and the slags yield about 20 per cent., the average being about 12½ per cent. The slags left by the Romans are the richest; but some left from smelting-processes, carried on about 50 years ago, yield lead in profitable quantities.

Joining the carriages on the Harptree Road, Mr. Parker pointed out that here the waters plunge into a swallet-hole at the junction of the Lower Limestone Shales with the Carboniferous Limestone, and re-issue at the surface near Wookey Hole. Some years ago this led to a law-suit, for the waters were so polluted by the lead-works that they became unfit for use at the paper-mill at Wookey, and the case was decided against the owners of the lead-works, who had to provide means for preventing any of the waste-water from descending the swallet.

Passing by the "Castle of Comfort," the carriages were driven along the West Harptree Road as far as Lamb Bottom, where a welcome halt was made for lunch.* A short walk afterwards brought the Members to the entrance to the Lamb Cavern,† which is situated a little to the north of the head of the Lamb ravine, and not far from the high road. The entrance to the cavern was carefully padlocked, but the Director explained that the descent was somewhat hazardous and would require more time than could be spared, although the cavern was a very spacious one and presented many points of interest. Attention had been called to it more than two hundred years ago by J. Beaumont, and subsequently by others, some of whom suppose it to have been an old mine. For nearly a hundred years it appears to have been quite lost sight of, the entrance being blocked up. It was rediscovered, however, in 1880, by Colonel Bolton, after no less than 37 trial-borings had been made, and it has been very fully described by Mr. McMurtrie,‡ who shows that while the entrance is artificial, and that here and there lodes have been worked, yet the main portions are all natural.

* The route was modified from that given in the programme, as it had been ascertained by the Director that the lead and ochre-works at East Harptree had been abandoned.

† Application to visit this Cavern should be made to Mr. Thomas Caple, of West Harptree.

‡ 'Proc. Somerset Arch. Soc.' for 1880.

The Director read some account of the cavern from Mr. McMurtrie's paper. Descending by a ladder down a perpendicular shaft, about 2ft. square and 55ft. deep, the explorer passes along a narrow passage and then down another and shorter ladder into a series of natural chambers. These lead by a steep descent into an immense cavern, about 100ft. in diameter and 110ft. at its highest part. Into this abyss the visitor is then lowered by means of ropes, and, slowly revolving, he reaches the bottom, after a descent of 77ft. from the gallery above. A passage from this great cave leads to other chambers, but they have not been fully explored. The roofs and sides of the chambers at different levels are draped with stalactites, and the floors are covered with stalagmite and red earth. No bones have been found, though it seems likely that systematic explorations would not be unrewarded.

The character of the descent called to mind that at the copper-mine of Dolcoath, visited many years ago by Sedgwick. On commencing the descent he asked a miner, "How far is it to the infernal regions?" And the man replied, "Let go the ladder, sir, and you'll be there directly."* The Director thought that, under the circumstances, he had not been justified in making arrangements for descending the Lamb Cavern. His object in bringing the Members there was to show the proximity of an extensive Cavern to one of the minor ravines in the Carboniferous Limestone. In the course of time the falling in of the roof of the cavern and subsequent denudation might so enlarge the Lamb Bottom that it might become as important as the gorges of Ebbor or Cheddar.

The Members walked a short distance down the rocky Combe, where *Cystopteris fragilis* and other ferns were seen in abundance. They now re-entered the vehicles and returning a short distance, proceeded along the East Harptree Road for about a mile and a quarter. Crossing a field on the eastern side of the road they came to a large circular hollow, evidently a swallet-hole. On the sides of this deep pit there jut out a set of hard cherty rocks, whose fossils have proved them to be of the age of the Lower Lias. Attention was directed to these beds in the early days of geology, for they

* 'Life and Letters of Adam Sedgwick,' by J. W. Clark and T. McK. Hughes, Vol. i, p. 332.

cover a considerable extent of land hereabouts, and have been largely used in the construction of the stone-fences. Thomas Weaver, in 1819, gave an excellent description of the strata, but referred the beds to the Greensand. Buckland and Conybeare, in 1823, noticed many of the fossils, but were led to associate the strata with the Dolomitic Conglomerate, which curiously enough likewise presents some siliceous modifications. De la Beche, in 1846, first pointed out the Liassic age of the beds on Harptree Hill, while the Director had subsequently written about them and published a list of the fossils.* These included *Ammonites planorbis*, *A. johnstoni*, *Cardinia suttonensis*, *Lima gigantea*, *Modiola minima*, *Myoconcha psilonoti*, *Ostrea liassica*, *O. multicostata*, and *Pecten pollux* (*suttonensis*). Exhibiting a specimen of the altered Portrush Lias containing *Ammonites johnstoni* (described as a cherty rock by Portlock, but in reality a kind of lydian-stone), the Director remarked on their somewhat similar texture. The term chert, however, was nowadays generally restricted to beds of organic origin, and the question of the origin of the Harptree Beds required to be reconsidered. Dr. G. J. Hinde had found one fragment of the Harptree rock in which sponge-spicules were present, but with this solitary exception he could find no trace of siliceous organisms.

Hammers were vigorously plied on these tough and splintery siliceous rocks, and fossils were found, but they were more readily to be obtained from the blocks used to mend the walls that bound the high road.

Returning towards the Castle of Comfort, a brief visit was paid to some hollows on Harptree Hill, from which hardened sandy beds, yielding *Avicula contorta* and *Pullastra arenicola*, had been obtained. These sandy beds had probably been derived from the neighbouring Old Red Sandstone.

After a short halt at the Castle of Comfort, the Members were driven by Bowery Corner, through the village of Priddy, and by Pitts Farm to the Mining Works belonging to the Somerset Manganese and Iron-ore Company, near Dursdon, at the head of Ebbor Gorge. Mr. Willcox again kindly explained matters to the assembled company. Deep trenches had been excavated in the Dolomitic Conglomerate, and a shaft had been sunk at one point to a depth of 62ft. in this rock. Near the

* 'Geol. East Somerset,' p. 105.

surface the rock was seen to contain nests of manganese-ore, and associated with this a little copper-ore had been found, and what was of especial interest the mineral mendipite (oxy-chloride of lead) had also been obtained. This mineral had been first noticed as a new ore of lead in 1823, by Berzelius, from a specimen in the collection of the Royal Academy of Sciences at Stockholm, labelled "Lead-spar from Mendip, near Churchill."* This was stated to occur in radiated masses, enveloped in manganese-ores, and associated with galena and hæmatite. The name mendipite was subsequently given by E. F. von Glocker in 1839.† It was interesting to find a new locality for this rare mineral, and to note that it occurred in a position similar to that at Churchill. In the present instance it was associated with cerussite (carbonate of lead). Hæmatite was also found in veins and pockets of the Dolomitic Conglomerate at these works.

The Members now walked towards the head of Ebbor Gorge, descending to the bottom of this picturesque ravine. It has been excavated in the Carboniferous Limestone, and was for the most part in a natural state, the *débris* that continually falls from the cliffs on either hand having accumulated as screes on the sides, or fallen to the bottom, so that, especially near the head of the ravine, the pedestrian has to find his own pathway among the tumbled blocks of limestone. It was a rough though pleasant scramble down the gorge, the most difficult way being at a steep and narrow passage called the Deer's Leap, evidently an old waterfall, down which it was needful to proceed circumspectly.

A little lower down Professor Lloyd Morgan joined the party, and pointed out a bed in the Carboniferous Limestone that is rich in corals. His observations had led him to differ from the Director in the interpretation of a little lateral valley that lies to the west of the Ebbor Rocks, and where the Geological Survey Map shows a small area of Millstone Grit and a narrow faulted belt of Lower Limestone Shales and Old Red Sandstone. He drew attention to the fact that the limestone at this spot was Upper Limestone, as shown by the *Lithostrotion*. This had a bearing on certain views which had

* See 'Edin. Journ. Science,' Vol. i, 1824, p. 379.
† 'Grundriss der Mineralogie,' etc., p. 604.

been formulated with regard to the adjoining Ebbor Valley, in which Lower Transition Beds (Lower Limestone Shales) and Old Red Sandstone had been mapped, faulted against Millstone Grit.* He had recently remapped the ground very carefully, and had come to the conclusion that there was no evidence of Lower Transition Beds or of Old Red Sandstone. Millstone Grit, or, perhaps, Upper Transition Beds, extended right down the valley, and in them there had been several fruitless trials for coal. His work at Emborrow had taught him that the Millstone Grit in the Mendip puts on an appearance closely resembling Old Red Sandstone.† He regretted that he had to differ from Mr. H. B. Woodward, for whose work he had the sincerest admiration.

The Director remarked with sorrow that he could not then discuss the subject with Professor Lloyd Morgan, as he had not yet seen the paper to which allusion was made, and was, therefore, unacquainted with all the evidence brought forward. He had, however, no doubt that Professor Lloyd Morgan's observations would fully justify a re-examination of the ground.‡

Tea was provided at a cottage near Wookey Hole, after which the Members proceeded to the famous Cavern, to which they had free admittance, through the kindness of Mr. W. S. Hodgkinson. The entrance to the cavern is in the Dolomitic Conglomerate, which here lies banked up against the Carboniferous Limestone. Each Member was provided with a tallow-candle, while Mr. Manning had kindly sent a supply of blue-fires. Thus equipped, the party one by one entered the cavern, and proceeded along its devious and somewhat muddy course, up and down, and frequently stooping to pass through the low passages. The largest chamber is about 80ft. high; but there are few stalactites to be seen. Neither have any organic remains been found, with the exception of human bones and pottery, of no great antiquity.§ Having reached the further end, where there was a large pool, the guide poured paraffin-oil

* H. B. W., 'Geol. East Somerset,' p. 19, and H. W. Bristow and H. B. W., 'Geol. Mag.,' 1871, p. 501.

† 'Proc. Bristol Nat. Soc.,' Ser. 2, Vol. vi, Part ii, Aug., 1890.

‡ Having since read the paper in question, I feel loth to express any opinion until I have again had the opportunity of hammering at the rocks.—H. B. W.

§ Recorded by Buckland, 'Reliquiæ Diluvianæ,' 1823, p. 165.

on to the placid water, and setting fire to it lit up this portion of the cavern. The blue-fires were now ignited here and there, so that the cavern soon became full of smoke and sulphurous vapours, and it was with some feeling of relief that many of the Members again emerged to daylight.

A short and steep descent brought the Members to the source of the Axe, whose waters emerge from the swallet-hole that conducts the springs from the surface of Mendip, near Priddy.

Proceeding a little further on towards the Paper Mill, and across the mill-stream, the Members now visited the small cavern excavated in the Dolomitic Conglomerate, known as the Wookey-Hole Hyæna-den. Bones had been discovered here in 1852, during the process of cutting a channel for the stream, and the den was subsequently explored in 1862-63 by Professor W. Boyd Dawkins,* aided by the Rev. J. Williamson, of Theale, and Mr. James Parker. Bones of hyæna, cave lion, rhinoceros, bear, mammoth, reindeer, *Cervus megaceros*, etc., had been obtained; many of them gnawed by hyænas. Palæolithic implements, fashioned out of flint and Greensand chert, had also been found, so that it had been concluded by Professor Dawkins that the cave had been alternately occupied by man and hyænas; and that the latter had brought in many of the bones, but that others had been introduced during times of flood. Mr. Parker expressed himself very sceptical about these conclusions, and pointed out that there was evidence of a fissure leading into the den from above, and he thought the bones had been introduced through it. Mr. Winwood, however, maintained that the evidence of the gnawed bones was irresistible, and we must consider that they had been dragged in by the hyænas. The discussion of these bones terminated the day's programme, and the Members now rejoined the carriages, and were driven through the hamlet of Wookey Hole, where the cottages are for the most part built of Dolomitic Conglomerate, back again to the Swan Hotel, at Wells.

Thursday, August 7th.—Glastonbury, Street, and the Polden Hills. (Director: H. B. WOODWARD.) The Members started by the 9.15 a.m. train for Glastonbury, where they arrived at

* 'Quart. Journ. Geol. Soc.,' Vol. xviii, p. 115; Vol. xix, p. 260. See also 'Cave Hunting,' pp. 295, 312, etc.

9.27, and were driven from the station, past the Abbey kitchen and the Abbey barn, to the foot of the Tor Hill. A few Members who wished to avoid the steep ascent of the "Isle of Avalon," however, remained in the town, and visited the Archæological Museum, under the guidance of Mr. T. C. Luff, a Member of the Association. This museum, formed mainly by the exertions of Mr. J. G. L. Bulleid, contains an interesting series of specimens, together with books and maps, to illustrate the antiquities and topography of the district.

At the foot of the Tor Hill the site of the chalybeate spring was pointed out. It was famous during the period of the Abbey's greatness, and regained notoriety about the year 1751. Dr. R. Russel, writing in 1769, however, remarked that "It is certainly destitute of those Virtues that the Multitude have ascribed thereto. . . . we are told, that many, by their injudicious drinking this Water, instead of being cured, were hurried out of the World. Some . . . believed the Virtue of the Water was owing to its passing over the Graves of holy Men."* There is, however, no doubt that the spring issues from the micaceous and somewhat ferruginous sands of the Middle Lias, being thrown out at their junction with underlying clays.

The Members rested awhile on the summit of the Tor Hill, which is about 500ft. above sea-level.† Unfortunately the atmosphere was hazy, and the otherwise fine prospect was eclipsed. The outline of the Mendip Hills could only just be discerned, and Brent Knoll, an equally prominent hill near the shores of the Bristol Channel, could not be seen. The alluvial plain contains several turbaries, or peat-moors, and also banks of recent marine sands at Burtle and Middlezoy. Glastonbury Tor presents the same general structure as Brent Knoll, but in the latter hill some *Ammonites* and *Rhynchonella cynocephala*, indicative of the Cephalopoda bed of the Cotteswolds, had been found,‡ whereas at Glastonbury no fossils had been discovered in the sands and concretionary masses of calcareous sandstone which form the higher and more distinctive portion of the Tor. These sands, conveniently grouped as the Midford Sands, rest

* 'Dissertation on the Use of Sea Water,' etc., Ed. 5, 1769, p. 295.

† In the 'Concise Guide to Glastonbury,' by G. W. Wright, the height of the Tor is stated to be about 520ft.

‡ H. B. W., 'Proc. Bath Nat. Hist. and Antiq. Field Club,' Vol. vi, p. 125.

on a platform of Upper Lias, whose basement-bed consists of pale argillaceous limestones, that have yielded *Ammonites bifrons*, *A. serpentinus*, *A. communis*, *A. crassus*, *A. holandrei*, *Belemnites*, *Nucula*, etc. These beds again repose on the Rock-bed of the Marlstone, here a thin band of tough iron-shot limestone, in which *Ammonites spinatus*, *A. margaritatus*, *Belemnites*, *Pecten æquivalvis*, *Rhynchonella tetrahedra*, *R. acuta*, etc., have been found. This Rock-bed was formerly worked for road-metal, but, alas, the small quarries were all closed and obscured, the Blue Lias from Street and the Carboniferous Limestone of Mendip being employed instead of the local stone. The general succession may be stated as follows* :—

		Feet.
Midford Sands	8. Sands, etc.	175
Upper Lias	7. Clay	35
	6. Basement Beds of Limestone, etc.	14
Middle Lias	5. Rock Bed	1.0 to 2
	4. Clays	10
	3. Micaceous Sands, with concretionary masses of Calcareous Sandstone	60
	2. Laminated Sands and Shales	140
	1. Clays (merging into the Lower Lias Clays)...	65

Beds 1, 2, and portions of 3 are exposed on Weary All Hill, and the Micaceous Sands (3) were well seen on the descent towards Glastonbury in a deep road-cutting on the north side of Chalice Hill.

The Tor itself and the surrounding low-lands and moors tell of great denudation. The Director said that, in imagination, we might fill up the plains with the higher beds of Lias and Midford Sands, etc., until the beds abutted against the Mendips as they do along the escarpment to the east. The denudation had been performed mainly in Post-Cretaceous times—after the Cretaceous rocks which formerly over-spread a wide area had been removed. Rain, rivers, and estuarine action had been the chief agents in performing the work; and we had to consider the action of streams, which collecting underground from the rainfall on porous beds, formed subterranean channels which eventually influenced the surface features. Glastonbury

* Dr. Wright, who published some account of Glastonbury Tor, over-estimated the thickness of the Rock-bed. 'Quart. Journ. Geol. Soc.,' Vol. xvi, p. 34. See also E. C. H. Day, 'Proc. Cotteswold Club,' Vol. iii, p. 121.

Tor, like Brent Knoll, presented evidence of gentle synclinal structure, which may have contributed to its preservation.

That Glastonbury Tor was not entirely surrounded by water during historic times, is indicated by the extent of the alluvium, which, as marked on the Geological Survey Map by Mr. J. H. Blake, does not isolate the hill. Nevertheless it was for all practical purposes an island, being surrounded by low-lying ground, in old times for the most part occupied by marshes, which were flooded in rainy seasons; and the name Isle of Avalon (used by William of Malmesbury) was not inappropriate.

It was on record that the body of the old church on the Tor had been overthrown by an earthquake in 1275, while the tower of that date remained. The Director thought that very likely the foundations of the nave had been weakened by the action of underground springs, which thus facilitated its overthrow.

On reaching Glastonbury town a visit was paid to the Abbey, where Mr. Parker gave a lengthened and interesting account of the ruins, and their history.* A short visit was also paid to the Archæological Museum (by those Members who had not previously seen it), when Mr. E. B. Sly, one of the Honorary Curators, kindly acted as guide.

The Members now entered the vehicles that were awaiting them, and driving along the foot of Weary All Hill, proceeded to the village of Street. This is a typical Liassic settlement. The houses for the most part are built of the Blue Lias, and many gardens are fenced off with slabs of the same stone. As a road-metal it is not to be commended, for a white dust or sticky mud are encountered, according to the nature of the weather. Near the centre of the village is Crispin Hall, dedicated to the patron Saint of the shoemakers, to whom the prosperity of Street is very largely due. The hall, which owes its existence to the liberality of Mr. William Clark, contains the Street Geological Museum, which was founded a few years ago by Mr. Alfred Gillett, a Member of the Association. To this Museum the Members now found their way, where they were welcomed by Mr. Gillett, who pointed out the general arrangement of the specimens and the objects they were

* For a particular account of Glastonbury see the 'Proc. Somerset Arch. and Nat. Hist. Soc.' for 1880.

intended to serve. Fossils from the Silurian to the most recent formations were carefully arranged in cases, and representatives of living species were also included for purposes of study. On the walls there were suspended some of the fine Saurian remains for which Street is so renowned a locality, and the Director called attention to a photograph of a very perfect though comparatively small specimen of *Ichthyosaurus tenuirostris*, which had been presented to the British Museum by Mr. Gillett, who had himself laboured for a twelvemonth in chiselling out the remains of this reptilian gem.

After leaving the Museum, the Members, preceded by Mr. Gillett, were driven to his residence at Overleigh, about a mile distant. Entering the grounds by a pathway bordered by flowers and shrubs, the Members assembled on the lawn in front of the house. There the fine trees, the beds gay with "old-fashioned" flowers, and the picturesque arrangement of the garden, devoid of all formality, made the scene one of a most charming nature.

A tent had been erected in the paddock adjoining the lawn, and thither Mr. Gillett conducted the Members, who found a very excellent repast prepared for them. It required no persuasion to do ample justice to this substantial mid-day meal. The Director briefly thanked Mr. Gillett for his kind hospitality, remarking that their host had long laboured in a quiet and unostentatious way in the pursuit of science, gathering stores of information and fossils which he freely placed at the disposal of others. During the progress of the Geological Survey in 1868, he had visited Street in company with his colleagues, J. H. Blake and W. A. E. Ussher, and he had lively reminiscences of Mr. Gillett's kindness at that time, and likewise of the fruit which they had gathered (not without permission) from his orchard. The present occasion was one that would be remembered as the most pleasant part of the day's proceedings.

Shortly afterwards the Members proceeded on foot towards the Polden Hills. An opening known as Seymour's quarry was first visited on the way, and there a good section was seen of the Lower Lias stone-beds, which are worked for building and paving-stone, and are also burnt for lime. These beds, which belong to the zone of *Ammonites planorbis*, occur in compara-

tively even layers of limestone, alternating with shales and clays, to the thickness of about 20ft. Each band of limestone has its local name, and these were pointed out by one of the quarrymen. From these beds remains of *Ichthyosaurus* and *Plesiosaurus* are from time to time unearthed, but much time and labour are required to develop the specimens. Fish-remains of the genera *Leptolepis*, *Dapedius*, *Amblyurus*, and *Pholidophorus* also occur. Invertebrate fossils are by no means abundant, but *Ammonites planorbis* occurs, and Mr. Gillett had lately obtained a specimen of *A. angulatus*. The more abundant fossils are *Lima gigantea* (small specimens), *Pleuromya*, *Ostrea liassica*, and *Rhynchonella variabilis*.

The saurian remains of Street had in the first instance been brought into prominent notice by Thomas Hawkins, who formerly resided at Sharpham Park (noted as the birthplace of Henry Fielding). Mr. Gillett exhibited a copy of Hawkins' big, though fancifully-written book, "Memoirs of *Ichthyosauri* and *Plesiosauri*" (fol. 1834).

On the summit of the Polden Hills, near Ivythorn, a fine view was obtained across the plains of Sedgemoor to the distant Quantock Hills on the south-west. A faint outline of the little island of Athelney was discernable, while the outliers of Lias and Rhætic Beds near Compton Dundon stood out conspicuously. The Polden Hills are formed by the escarpment of the Lower Lias and Rhætic Beds overlying the New Red or Keuper Marls, the northerly dip bringing on higher and higher beds of Lias as we approach Glastonbury. Allusion was made to the old boring for coal made in 1815, near Compton Dundon; but though a depth of 519ft. had been penetrated, the base of the New Red Beds had not been reached.* To do this it might be necessary to bore 1,000ft., but, although the area to the south of the Mendips was a promising one, as pointed out nearly 70 years ago by Buckland and Conybeare,† private enterprise could not be recommended in the search for coal.

Evidences of faulting are frequent along the Polden Hills, and here and there traces of White Lias were met with in abrupt juxtaposition to the Lower Lias. Some fossils were

* Moore, 'Quart. Journ. Geol. Soc.,' Vol. xxiii, p. 457.
† 'Trans. Geol. Soc.,' Ser. 2, Vol. i, p. 264.

obtained from a shallow opening in the White Lias, about a mile westwards of Ivythorn. There the junction with the Lower Lias is not very distinct, but usually the upper limit of the White Lias is marked by a hard and compact limestone, locally called Jew Stone or Dew Stone,* equivalent to the Sun Bed of the country about Radstock and Bath.

Returning along a footpath to Street, under the guidance of Mr. S. T. Clothier, another Lias quarry was visited, and here a sharp anticlinal was seen to disturb the beds at one point, a feature which had been preserved through the influence of Mr. Gillett, so that the Members might have the opportunity of seeing it.

Returning for a short time to Overleigh, the President (Mr. T. V. Holmes) proposed a cordial vote of thanks to Mr. Gillett for the kindness he had shown to their large party. The Members then proceeded into the village of Street, where Mr. and Mrs. Frank Clark and Mr. Clothier had most kindly provided tea. The time unfortunately was short, but the halt was none the less welcome. The Members were then driven to the Glastonbury station, whence they returned by rail to Wells; the Director unfortunately having to leave for London.

Friday, August 8th.—Cheddar Pass and Weston-super-Mare (Director: Rev. H. H. Winwood).—Wells was left by train at 9.55 for Cheddar. Some of the party drove, others walked, from the station through the village; and all met opposite Mr. Gough's stalactitic cavern. After a due inspection of the interior recesses with their usual drapery of stalactite and stalagmite, to which the rustic imagination has given the most absurd and fanciful names so attractive to the "tripper," the party were not sorry to return to the light of day and wander up the grand ravine, stopping at various points to admire the towering and perpendicular rocks on the right hand, or south side, attaining a maximum height of 420ft. About half-way up the pass a fissure was visited, and by the aid of petroleum the innermost recesses were lit up, showing how the heart of these hills are being eaten into by the mechanical and chemical action of water, and a cavern is in process of formation. Ascending nearly to the top of the pass a short scramble to the left was made to a narrow ravine opening out from a small cave on the

* The term probably is of Celtic origin. Dhu stone (*i.e.*, Black stone) is the local name for the Clee Hill basalt.

north side of the slope, which the Director called the "Dawkins cavern," and said he would take this opportunity of making a few remarks on the origin of the gorge just seen. The term "cliff" given to the Cheddar Pass was, perhaps, misleading, for that term generally applied to the rocks on a sea coast, and in his opinion the sea had nothing whatever to do with the physical features before them. There were three theories started to explain them: 1. The action of the sea. 2. The result of an earthquake. 3. The mechanical and chemical action of water.

He would briefly mention the arguments in disproof of the two first. With regard to the sea, the winding nature of the ravine, projecting angle on one side accurately corresponding and fitting into re-entering angle on the other, was sufficient proof that the sea, generally a planing and levelling agent, had nothing to do with it. Then as to the second, *i.e.*, earthquakes, whereby one side was rent open from the other (an old world notion now generally discarded); this was disproved by the dip of the beds in the same direction, *i.e.*, south, varying, as Mr. Blake, who was with them to-day, had stated, on one side from 19° and 24°, to 15° and 23° on the other. Moreover, why should the rent have ceased suddenly at the base?—the beds having been proved to be solid and continuous under the road (Fig. 4, p. 493, *infra*). It now only remained for him to speak of the last, *i.e.*, the chemical and mechanical action of water. This view, originally started by Professor John Phillips, and since so ably advocated and worked out by Professor Boyd Dawkins, he adopted. Lines of weakness, joints, and fissures, becoming originally underground watercourses, would, through the dissolving and wearing-away action of the water, develop into caverns. One has only to penetrate into these hills to find them honeycombed with evidences of this; these underground watercourses finally emerging at lower levels owing to alteration of drainage, the mouth of these caverns in process of long ages falling in bit by bit, and becoming open ravines, rain, frost, and other agents loosening blocks from the sides,—and there was sufficient agency to account for ravines such as these. The cavern near which they were standing was one to which Professor Boyd Dawkins many years ago had directed attention as in process of formation into a ravine, the roof

being eaten into bit by bit, and the ravine extending backwards at the latter's expense. The fallen blocks on the floor, did they care to enter, were evidence of this; indeed, he had noticed that quite recently fresh blocks had fallen down.

Mr. James Parker was called upon by the President to say a few words, and, as might be expected, he wholly disagreed with the Director. Mr. Parker said he was glad to hear Mr. Winwood admit other forces having been the cause of the Cheddar Pass and similar valleys besides water. It was, to his mind, something to get that admission, slight as it was, when he remembered views put forward on the occasion of the Association visiting the Cheddar Pass some ten years ago. The point on which he differed from Mr. Winwood was, to put it briefly, this; Mr. Winwood attributed the formation of the gorge, and all the phenomena which belonged to it, to results first arising from upheaval, and then from the action of water; in the proportion of one-fourth or less, as far as he understood his argument to the first force, and three-fourths or more to water. He (Mr. Parker) attributed 999 parts out of a thousand to fracture, and the remaining thousandth part to the action of the water, and this action, so far from extending the valley and fissures belonging to it, had, if anything, the effect of apparently reducing them. Mr. Parker then went into the question of upheaval. He objected to this view, as he believed the phenomena which they saw were produced by unequal depression of parts at a distance from the unyielding axis or main anticlinal of Mendip, and that any upheaval which had taken place would be only incidental. The depression had been going on from the time of the deposition of the Old Red, which still remained covering the axis, and this depression, he contended, was due mainly to the contraction of the earth's surface from causes which he could not, in the two or three minutes at his disposal, discuss. His view was that this unequal and irregular contraction, subject as it was to varying circumstances, produced the main fractures and the accessory fissures, which went to make up the phenomena which presented themselves in the Cheddar Pass; that such action of water as may have supervened was so slight in its results that it was scarcely worth taking into account; and that the particular fissure which they had come up to see was only one out of thousands,

which were only incidental, and played no primary part, such as Mr. Winwood had attributed to them, in the formation of the valleys.

Mr. J. H. Blake asked whether the Director considered that the pass was only one huge unroofed cavern, or a series of them, and the reply being "a series," added an important fact regarding the water, *i.e.*, that in past times the hills, now almost bare of trees, were covered with a dense forest, and, consequently, the action of water, both chemically and mechanically, must have been much greater then than now.

Whilst some of the party returned down the pass, the rest followed a path up through the fir wood, on the south side, and obtained a grand view from the top, extending over the rich alluvial lowlands at their feet, with the Carboniferous outliers of Nyland and Lodge Hill standing out like islands; Brent

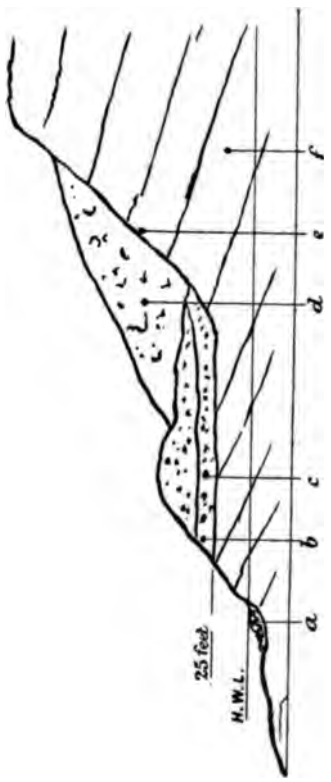


FIG. 8.—SECTION BY E. C. DAY OF RAISED BEACH AT BIRNBECK COVE, WESTON-SUPER-MARE.

From the 'Geol. Mag.,' 1868, p. 115.

H. W. L. High-water level.
25 feet. 25 feet above high-water level.
a. Modern beach.
b. Ancient beach.
c. Ancient sand-dunes.
d. "Head."
e. Ancient cliff.
f. Carboniferous Limestone.

Knoll on the right, with its capping of Midford Sands and Cephalopoda bed; Glastonbury Tor on the left, and the distant Old Red Sandstone of the Quantocks on the horizon, with the streak of Severn's sea glimmering along the Welsh line of coast in the far distance. After a few minutes spent on the sunny slopes enjoying the view, a rapid descent to the road below was made, and the 2.51 p.m. train taken for Weston-super-Mare.

After certain preliminary arrangements had been made at the Atlantic Hotel, as there was time to spare before dinner, Mr. Parker went off with one or two to visit the Uphill Caves, with which he was familiar, whilst the Director conducted the rest to the raised beach at Birnbeck Cove, opposite the island of that name (Fig. 8). Here, at a height of about 25ft. above the sea-level, is a consolidated mass of water-worn pebbles, some three or four feet thick, apparently jammed in between the Carboniferous Limestone beneath and a bed of yellowish-looking limestone above. From below it looked more like a patch of Dolomitic Conglomerate than a raised sea beach, but two or three adventurous climbers, headed by the active and worthy Secretary, extracted some recent shells, *e.g.*, *Littorina littorea* and *L. littoralis*, from the matrix, thus setting at rest the former hypothesis, and proving its recent origin. Horse teeth, moreover, are reported to have been found here also.

On the other side of the road and immediately above this blown sand is seen. Only a small patch of this, however, is visible, the rest having been dug out with the talus of loose angular limestone blocks, with which it is intermixed for road material.

The following are Mr. Thomas Leighton's remarks on the Mollusca.

From the blown sand over Raised Beach :—

Tellina balthica (*Linn.*).—Two fragments, both of right valves. The first specimen found was projecting horizontally from the face of the section (weathering out). The edges of fracture are so sharp and fresh that there is no doubt it was broken off in working out. It is a young shell, thin and fragile, but quite unrolled and otherwise in good condition. The leafy fold forming the cardinal tooth is broken off; which fact, accompanied by the prominent umbo of the young shell, gives the hinge rather a strange appearance. That it is a "dead shell" is proved by traces of *Serpula* on the inner side. Some of the sand still adheres to the shell, the grains

appear rounded, but resisted all efforts to remove them for further examination. The larger specimen was found on the surface of the section, eight or ten feet up (from the road), on a small runlet of rainwash. The fractured edges are old; it does not appear to have been rolled since fracture, however, although possibly before, the details of the hinge having been dissolved away almost entirely. It is a right valve of a full-grown shell, but quite in a sub-fossil condition.

From the Raised Beach :—

Littorina littoralis (*Linn.*).—I have extracted two specimens, both more or less fragmentary, which I refer to this species. The more perfect specimen is abraded posteriorly, the internal structure being thereby laid open. The inclination of the columella, although somewhat crushed, together with the broad expansion of what remains of the body-whorl give sufficient evidence of the affinities of the specimen. The second specimen, a mere fragment, shows, however, the characteristic angular posterior, which is wanting in the former specimens.

Littorina rudis (*Donovan*).—I give this species with some hesitation, as part of the evidence is lost. When found, the spire was imbedded in the hard conglomerates; the mouth and anterior portions of the shell, however, were beautifully weathered out of the hard specimen. I named it *rudis* on the spot, and in attempting to extract the shell from the matrix there and then, unfortunately chipped off the outer lip and end of the pillar. Now that the specimen has been properly worked out the evidence is clear to my own mind, and I call attention to the angle made by the outer lip with the body-whorl, and to the roundness of the whorls themselves as characters, amongst others, which are incompatible with *littorea* (*Linn.*), the only other species to which it could be referred.*

A dinner at the Atlantic Hotel closed the day.

Saturday, August 9th.—Steep and Flat Holms (Director: Rev. H. H. Winwood).—This was a memorable day. The steamer *Merrimac* having been especially chartered for the occasion, and the party being increased by the addition of C. Richardson, C.E., Professors Lloyd Morgan and Sollas, an early start was made from the Birbeck Pier at 9.45 a.m. on what the programme described aptly as a "voyage of discovery," as few, if any, of the party knew much of the geology of these isolated masses of Limestone, the last outliers of the Mendip anticlinal. Leave having previously been obtained from Col. Tyler, the Commandant of the district, to land and visit the fortifications, after a steam of forty minutes, the distance being from four to five miles, the first boatload touched the beach of the Flat Holm, on the south-east side, at 10.35. The Carboniferous

* The occurrence of these two species is mentioned by Day, 'Geol. Mag.,' 1866, p. 116.

Limestone Beds, thin and somewhat flaggy, containing corals, gasteropods, *Cyathophylli* and *Euomphali*, dipped here at an angle of from 20° to 25° S.S.E., and apparently belong to the Upper Limestones. Just behind the outhouse attached to the now ruined Inn, a slip fault occurs, and further on, about the centre of the east face, the beds appear to form a synclinal rolling over sharply to the north. Ascending the steep path to the top, attaining a maximum elevation of 237ft., and following the winding path leading to the batteries, the strata at the "Summit Battery" on the north of the cliff show a series of thin beds dipping 60° N.N.W. At the "Rudder Battery," at the north-west end, the rocks beneath seem nearly perpendicular, Behind the men's quarters, snugly ensconced on the south side, the beds assume the normal south or south-east dip, and a fissure occurs here filled in with a yellowish deposit, similar to other infillings on the mainland. Formerly the head-quarters of Scandinavian pirates, and said to have afforded refuge to the mother of Harold after the battle of Hastings, and subsequently occupied by a small commandery of the Knights of the Temple, this islet, in the parish of Uphill, about 1½ mile in circumference, and containing sixty acres of rough grass land, is the property of Col. C. K. Kemeys-Tynte, by whom it has been leased to the Government for defensive purposes. The peony (*Pæonia Corallina*, Retz) has long grown here, but is not indigenous, and the flora is said to be poor. Re-embarking at 11.35, the *Merrimac* steamed round close in on the south side, which exhibited a series of pretty rolls and small faults, with a general south or south-east dip, until rounding the north-west corner, where the strata seem apparently to be on end; but whether this was the true dip of the beds or the joint-faces was rather open to doubt, as the bedding-planes were difficult to trace as the steamer passed quickly by; but perhaps the latter opinion mostly prevailed. The general structure of the island is a steep anticlinal, in any case: but whether inverted or not must be left to more accurate investigation to decide.* Whilst crossing the 2½ intervening miles a small steam-launch was passed, conveying General Sir R. Harrison on a tour of inspection of the batteries. Our flag was dipped by way of salute, but met with no response; and at 12.20 we landed at the

* See Buckland and Conybeare, 'Trans. Geol. Soc.,' Ser. 2, Vol. i, p. 233.

north-west corner of the sister islet, the Flat Holm, on a beach composed of largish limestone blocks, intermixed with rounded Chalk flints. The strata form low anticlinal and synclinal folds at this part. The beds on the north side dip at an angle of 23° 45′ E. of magnetic north. The "head," consisting of reddish loam, with a few quartzite and flint pebbles, rests on a low anticlinal of Carboniferous Limestone. Walking across to a landing-place on the north-east side, the party sat down for a while upon a beach composed of small pebbles of yellow-coated flints, quartzite, red and purple porphyry, Lydian-stone, granite, jasper, and limestone. A discussion as to the source of these pebbles ensued, and opinions were much divided, some maintaining that they were deposited by a current bringing the materials from some of the rivers on the Welsh coast draining the Palæozoic lands on that side; whilst a few held that the pebbles were ships' ballast thrown out at Cardiff and elsewhere to the north. This latter view, however, was not supported by the fact, afterwards ascertained from the master gunner, that thousands of tons were taken away by ships coming here for ballast, or by the statement of the skipper of the *Merrimac* that the tides sweeping round the island from the south and west met at this point. The walk was resumed round to the south-east, where the cliffs attain their maximum height of 40ft. Further progress was stopped by a deep ditch cut out of the live rock enclosing the batteries and the Lighthouse, 80ft. high. Following this ditch to the north-west side, the fortified enclosure was entered, and some time given to the inspection of the Moncrieff guns and their working, and before re-embarking a well on the west side was visited. This well, some 30 or 40ft. deep, has the peculiarity of filling at ebb and emptying at flow tides.* The water is brackish. Mean spring tides rise to a height of 38ft.; mean neap to that of 21ft.

Re-embarking at 2.15 p.m., we steamed round the east side and landed at Weston Pier 3.5 p.m., in time for those who wished to catch the express train for London.

Mutual farewells were taken and congratulations on the success of the Excursion, upon which the sun shone, with scarcely any exception, the whole of the six days, a memorable feature of this otherwise rainy summer!

* Whether this is so or not should be carefully investigated. Ray mentions a similar but groundless belief as to St. John's Well, Newton, near *Llandaff*. Itinerary, iii., p. 177. ed. 1846, Ray Society.—Ed.

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On The Causes of Volcanic Action.

By J. Logan Lobley, F.G.S., etc., Professor of Physiography, City of London College.

(*Read December 7th*, 1888.)

In his comprehensive and very valuable work on Volcanoes, Professor Judd, after having given a great amount of thought to the subject, and after a large amount of personal investigation of volcanic phenomena, writes as follows:—

"The inquiry concerning the nature and causes of volcanic action is far from being a completed one. It is true that many hypotheses upon the subject have been framed, but in too many instances these have not been based on accurate observations and careful generalizations, and can be regarded as little better than mere guesses. Indeed, the state of the inquiry at the present time would seem to be as follows. Although much remains to be done in the direction both of observation and experiment, the main facts of the case have been established upon irrefragable evidence. The classification and comparison of these facts have led to the recognition of certain laws which seem to embrace all the known facts. To account for these facts and their demonstrated relations to one another, certain tentative hypotheses have been suggested; but in no case can it be truly said that these latter have so far stood the test of exact inquiry as to deserve to rank as demonstrated truths. A complete and consistent theory of volcanic action still remains to be discovered."

More recently still, Dr. Geikie, in his 'Text Book of Geology,' published in 1885, says:—

"The *modus operandi* whereby the internal heat of the globe manifests itself in volcanic action is a problem to which as yet no satisfactory solution has been found."

These very recent statements, by two authorities of undisputed weight and eminence, appear to justify, or at least to excuse, any attempt that may be made, if not to find a complete solution of

the problem, at all events to contribute something to the discussion of a question that has appeared of sufficient importance to occupy the attention of many of the most distinguished men of science of the last and present centuries.

The difficulty of finding a theory to which some one or other of the very many, in some cases apparently conflicting, facts of volcanic phenomena does not seem to be at variance must be obvious; and there is little wonder, therefore, that opinions widely differ, or that the discussion of the causes of volcanic action seems to promise to be well-nigh interminable. Still, it should be borne in mind that some of the most eminent observers, thinkers, and logicians amongst geologists have made vulcanology a special study, with the result that a very great amount of data has been accumulated, forming, we may hope, an approximately complete and firm foundation on which to build the long-desired conclusive superstructure of this branch of geological science.

The sister branch, seismology, has during the last fifty years made great advances through the continued and assiduous observations and researches of Mr. Mallet, and more recently of Professor Milne, in Japan, and both of these authorities have brought their special knowledge and experience of earthquakes to the elucidation of volcanic phenomena. Professor Palmieri and Dr. Johnston Lavis are patiently watching every phase of Vesuvian action; a seismic observatory, like that on Vesuvius, has been established on Etna, and, not to mention foreign savants, Professor Judd has specially visited various volcanic regions to obtain facts and make observations that might throw light on the question. We are, therefore, now in a much better position than ever before to obtain a satisfactory solution, and it may be confidently hoped that, as far as is possible from the nature of the subject, the matter may soon be set at rest.

To justly estimate or adequately appreciate the value of any theory or hypothesis, it is necessary, before all things, that the facts to be accounted for should be fully recognized and constantly borne in mind. I have accordingly prepared a statement of the leading and controlling facts connected with volcanoes and volcanic phenomena. While endeavouring to make this compendium sufficiently comprehensive, each of the facts is stated briefly, but, I hope,

clearly as well as concisely, and the whole have been numbered for subsequent reference.

Compendium of the Chief Facts Connected with Volcanoes and Volcanic Phenomena.

1. The outputs of volcanic eruptions relatively to the bulk of the globe are individually infinitesimal; and, in their aggregate, form only a small part of even the visible surface of the earth.

2. Astronomical calculations, ocean tides, and the general stability of land and sea during long periods, demonstrate great rigidity of the solid exterior of the globe, and consequently a great thickness of solid rocky substructure.

3. There is no general constant flexibility or mobility of the earth's exterior, subsidences and upheavals being confined to certain areas and limited to certain periods, while some subsidences and upheavals are confined to very small areas, as the Bay of Baiæ.

4. The general inorganic and climatal conditions of the earth's surface were generally similar in Palæozoic to those of Neozoic times, as shown by similar organisms, ripple-marks, worm-burrowings, rain-pittings, etc.

5. Palæozoic volcanic action does not appear to have been greater than Neozoic, and the highest mountain ranges of the globe have received a large amount of their present elevation since the close of the Secondary period.

6. The specific gravity of the whole globe is only 5·5, while that of cognizable rocks is over 2·5, although Walterhausen calculates the pressure at the centre to be equal to 2,498,600 atmospheres, and Laplace 3,000,660.

7. Heat has been found to increase with distance from the surface at a rate that if continued would give rock-fusion, under atmospheric pressure only, at from 25 to 30 miles (in some areas the rate of increase is greater) and at half the distance to the centre a temperature equal to that of the sun, an impossible heat. There is, therefore, not a continued uniform increase of heat.

8. Rock-fusion, resulting from simple relief of vertical pressure in subterranean regions where the heat is sufficient to fuse rocks under

surface conditions, would not be limited in lateral extension if there is an open vent, and surface depression and derangements, with consequent lava outputs, on a scale far transcending any terrestrial catastrophes that have ever occurred, would result.

9. Volcanic action has gone on for long periods of time in many areas without causing any surface derangements except the building up of cones or the rupture of very small areas.

10. Areas of great volcanic activity in Palæozoic and even in Tertiary times, although still contiguous to the sea, are, and have been through immense periods of time, perfectly unvolcanic, as the Southern Hebrides; and insular volcanoes in more recent times have become quite extinct without change of geographical conditions, as in Madeira and the Canary Islands.

11. Lavas from different volcanic regions, though having a general resemblance, are not the same in composition, and some present considerable differences.

12. Lava solidifies with a small loss of heat, small quantities solidifying rapidly, and many lava flows are very inconsiderable in volume.

13. The products of the same volcanic centre at different periods may be respectively trachytic and augitic, as those of the Alban Hills; or may be characterized by different mineralogical features as those of the Somma-Vesuvian centre, while trachytic and augitic lavas may respectively characterize two vents in the same volcanic region, as in the Neapolitan.

14. A sequence of volcanic rocks has been detected, and may be stated as follows according to Richthofen:—I. Propylite (Earliest); II. Andesite; III. Trachyte; IV. Rhyolite; V. Basalt (Latest), in other words the earlier lavas of the same volcanic centre are usually trachytic or acidic, and the later lavas augitic or basic.

15. Sudden eruptive energy may occur where no volcanic vent previously existed, in some cases followed by a continuance of activity, as at Jorullo; and sometimes after a brief outburst, followed by perfect quiescence, as at Monte Nuovo.

16. Two volcanic craters on the same dome may not be sympathetic in activity, as Kilauea and Mauna Loa.

17. The eruptive axes of volcanoes sometimes vary their position, as in Vulcano and Vulcanello.

18. The volcanic foci of Etna and Vesuvius were calculated by Mallet to be only a few miles deep.

19. There are permanent hot springs in non-volcanic districts, indicating long-continuing, uniform, and considerable heat at no great depth, as at Bath, Clifton, etc.

20. The chief Northern European Tertiary volcanic outpouring, that of the lavas of Antrim, Iona, Staffa, and Mull, was in the same geological epoch as the great Central European subsidence, that of the Alpine region; and the great Central European Tertiary outpouring, that of the lavas of Auvergne, central Germany, Bohemia, and Hungary, was contemporaneous with the principal Central European Tertiary elevation, that of the Alps.

21. Volcanic action generally is in rising rather than in subsiding areas.

22. Volcanoes, though sometimes in groups and sometimes isolated, have by far their greater number arranged in linear extension, and this is round the chief water area of the globe, the Pacific Ocean, marking the commencement, on their eastern and western sides, of the great land masses, and coinciding with a line of elevation on the crest of which the volcanic vents are situated.

23. Active volcanoes, with few exceptions, are either in the sea (insular or sub-marine), or are on coasts either contiguous to or at but little distance from the sea.

24. Inland extinct volcanoes were near the sea or sea-like lakes at the period of their activity, as in Auvergne and Hungary.

25. The extinction of volcanic activity has followed the removal of the coast line to a very moderate distance, as in the Roman Campagna.

26. Steam is a most abundant, and sea-salt a prominent product of explosive eruptions, and all the elements of sea-water are contained in the ejectamenta of explosive volcanoes, while some volcanic tuffs consist largely of marine Diatomaceæ, as in Patagonia.

27. Nitrogen and various chlorides occur as volcanic products.

28. Volcanic phenomena seem to be absent from oceanic or deep sea bottoms.

29. Some eruptions are altogether explosive, as those of Vesuvius, A.D. 79, Monte Nuovo, and the recent one of Krakatoa; while some are altogether non-explosive and merely quiet emissions of lava, as those of Mauna Loa.

30. Neither Daubrée's or any other experiments have shown that

water either by capillary transmission or by fissures will pass through massive rocks bordering on a fusion temperature.

31. Enormous flows of lava have occurred without explosive effects, and there are vast beds of lava-rock that have not been, when fluid, associated with any volcanic cones, as in Antrim, Abyssinia, and Idaho.

32. Plutonic igneous rock-beds and dykes have been formed without explosive effects.

33. The volcanic tubes of the non-explosive craters of Mauna Loa and Kilauea are surrounded by solid, always hot, lava-rock, and in the products of these craters chlorides are rare.

34. Volcanoes quite dormant for many centuries have sometimes commenced a new epoch of activity, as Vesuvius; and sometimes after one eruption, have relapsed into complete quiescence, as Epomeo.

35. "Eruptive action is characterized by spasmodic fitfulness" (Geikie), and frequently the most violent eruptive phenomena are exhibited at the close of a lengthened period of Strombolean activity.

36. "When explosive force is spent, lava rises in vent" (Judd).

37. Feeble volcanic action may continue for centuries without change, as at Stromboli and the Solfatara.

38. Pressure caused by shrinkage of the earth's crust is tangential, not vertical.

39. The heat produced by crushing pressure of rocks is not localized at the points of contact, but disseminated through the rock-masses synchronously with production.

40. Observations of the activity of Stromboli and Vesuvius seem to indicate an approximation to periodicity of eruptive energy coincident with (1) autumn and winter; (2) the lunar syzygies; and (3) with hygrometric atmospheric conditions.

41. 2,000,000 tons pressure are removed from every square mile of the earth's surface when the barometer falls two inches.

42. Vegetable remains have been present in volcanic mud and water, and fishes, such as live in the local caverns, ejected; while remains of fresh-water diatoms were found by Ehrenberg in volcanic rocks of the Rhine, and in the Island of Ascension.

43. Immediatly before or at the commencement of eruptions the water in neighbouring wells falls, and the sea recedes, followed by a returning wave.

44. Antecedent to eruptions, earthquakes, earthquake shocks, or earth tremors occur, especially and more violently previous to the opening of new vents, as Jorullo and Monte Nuovo, and after long dormancy, as before the first historic eruption of Vesuvius.

45. Though great volcanic activity may be noted at particular periods, yet no sympathy between the eruptive energy at two well-separated vents has been with certainty found to exist.

To examine in detail, by the light of the foregoing facts, the various theories that have been propounded to account for volcanic action, could not be done in a paper of suitable length for this Association. It will be necessary, therefore, for me, before submitting my own conclusions, to be content with a very brief statement of these theories, and only to refer, numerically, to those facts in the above Compendium which appear to me to be conflicting or at variance with each of the hypotheses that may now have adherents and advocates.

Lemery's hypothesis, requiring great subterranean stores of sulphur in contiguity with metals, is worthy of reference, since it was, perhaps, the earliest theory that ascribed volcanic phenomena to comprehensible causes, and as it employed chemical combination it had a basis in common with the more advanced hypothesis of Sir Humphrey Davy.

To Lemery's succeeded Breislack's petroleum theory. Both were obviously due to the absence of the extensive knowledge obtained by the great amount of more recent travel, exploration, and educated and careful observation.

The chemical hypothesis of Sir Humphrey Davy, necessitating immense masses of certain unoxidized metals brought into contact with water, commanded great attention, from Davy's recent discoveries and great position. Its championship by Daubeny, and the great deference paid to its essential principle, that of chemical combination producing heat, by Lyell, ought always to prevent its being treated with disrespect. It was, however, ultimately discarded by its author and by its advocate, Daubeny, and does not now appear to be held by any vulcanologist.

The hypothesis of a thin shell or crust (25 or 30 miles thick) filled with a mass of fused matter which is pressed through cracks, fissures, or tubes in the solid surrounding crust by its slow contraction from secular cooling, had an able champion in M. Cordier, and

has had many supporters quite down to the present time. To me, however, it seems to be in conflict with facts 1, 2, 3, 4, 5, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24, 25, 26, 28, 29, 35, 38.

Seeing the difficulties of a thin shell, many have advocated a thick shell, while still holding fast the idea of a common central source of fused material. I cannot reconcile this view with facts 1, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 25, 26, 28, 29, 35, 38.

A later hypothesis is, that whether there be a thick crust with fused interior or an altogether solid interior, there is sufficient heat to produce fusion at a depth of 25 or 30 miles when extreme pressure is removed; and, that as this may be locally removed by lateral or tangential pressure, local masses or lakes of fused material may exist in separate regions of the earth's crust to which water from the sea may get access, and thus all volcanic phenomena may be easily accounted for. Though this hypothesis has been held and advocated by distinguished vulcanologists, and is now favoured by many eminent geologists, I venture to think it is not in accordance with facts 1, 8, 9, 10, 12, 16, 18, 28, 29, 30, 31, 32, 33, 36, 37.

Mr. Hopkins, whose calculations led him to require great rigidity, supposed an almost solid globe, with reservoirs of the original fused matter left at various distances from the surface, some being sufficiently near, with the aid of penetrating water, to produce the volcanic phenomena of the surface. This is opposed, I think, by facts 5, 12, 13, 16, 20, 21, 22, 28, 29, 30, 31, 32, 35, 36, 37.

Opposing the theory of fusion being caused by removal of pressure, Mr. Mallet advocated the hypothesis that the tangential pressure consequent upon shrinkage of the earth's exterior would produce so great heat at certain points that rock-fusion would take place, and the resulting fluid matter would by the same pressure be forced to the surface, there to produce volcanic phenomena. I cannot reconcile this theory with facts 1, 4, 5, 9, 10, 14, 15, 16, 23, 24, 25, 26, 28, 29, 35, 39.

Dr. Sterry Hunt supposes that after having been solidified, the exterior of the globe by an igneo-aqueous fusion, from an access of water from the surrounding gaseous envelope and the internal heat, became again fluid, receiving subsequently a hardened external crust, through which lava would be forced by vertical pressure

from the crust's shrinkage, and that the water of volcanic eruptions is the water of the hydro-thermal fusion. This is opposed, I think, by facts 1, 2, 4, 5, 11, 12, 13, 14, 16, 18, 20, 21, 23, 24, 25, 26, 28, 29, 35, 37, 38.

The Rev. Osmond Fisher, while accepting Sterry Hunt's central solid nucleus and crust of 30 miles thickness, with inter-layer of fused matter, cannot assent to his theory of the origin of the volcanic water or to the dogma of its descent and passage through highly-heated rocks, and so propounds the bold hypothesis that the steam given forth by volcanic lavas is the result of an extravasation of a primogenial "water substance" in the molten matter of the earth's interior. I am not able to accept the opinion that lava flows, or I might rather say lava rills, make their way through 30 miles of rocks, or that water in any form is the motive power propelling lava from its source, and I must meet this hypothesis with facts 1, 2, 11, 12, 13, 14, 16, 18, 20, 21, 22, 23, 24, 25, 26, 28, 29, 31, 32, 33, 35, 38, 42.

The latest view is that of Professor Prestwich, who, while adhering to the old opinion that the source of lava is below the crust of the globe, which gently presses upon the fluid mass from continued slow cooling, and so forces the lava through whatever vents may exist, considers that the water of volcanic eruptions is derived in the first place from land surface water, and subsequently from the sea after the lava has risen in the volcanic vent. In this Professor Prestwich approaches an opinion I have for some time held, in opposition to all I had seen written on the subject, namely, that the water of volcanic action is met with by the lava not far below the surface, but I cannot agree with the learned professor either as to the source of the lava, the cause of its rise in the volcanic tube, the importance of land surface water, or the secondary and subordinate place assigned to sea water. Neither can I agree with Professor Dana that deep-seated water may be a constant force and surface water a secondary force, since I do not believe there is any deep-seated water at all, that is, any in the neighbourhood of volcanic foci.

To Professor Prestwich's views I would oppose facts 1, 2, 3, 4, 5, 11, 12, 13, 14, 16, 18, 20, 21, 22, 23, 24, 25, 26, 27, 33, 37, 38.

To summarize my objections to these various hypotheses, I may say that I am opposed to —

(1) A common infra-crust source of lava.

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To summarize my objections to these various hypotheses, I may say that I am opposed to —

(1) A common infra-crust source of lava.

(2) The passage of what are comparatively insignificant quantities of lava through 30 miles of rocks, and consequently through all greater thicknesses.

(3) The ejection of lava from its source by vertical pressure.

(4) The ejection of lava from its source by steam force.

(5) The passage of water from the sea through deeply-seated hot rocks, whether by open fissures or by capillary transmission.

(6) The accumulation or the presence of water at volcanic foci.

(7) The primogenial "water substance" source of volcanic water.

(8) The importance of land surface-water.

In submitting the conclusions that seem to me not to be in opposition to the great facts of volcanic phenomena, I must express my regret that I can now only do little more than simply present them to this Association, and must reserve any more lengthy or complete advocacy for another occasion.

A. THE PRIMARY CAUSE OF THE FORMATION OF FLUID LAVA appears to me to be the internal heat of the globe inducing chemical, and possibly electrical, action in subterranean regions where the chemical composition of the rocks and their contained and associated minerals are favourable, and when, moreover, the conditions become more favourable by the removal of the restraining vertical pressure of the superincumbent rock masses by the counteracting lateral or tangential pressure produced by secular cooling causing shrinkage.

In this view there is room for the operation of chemical combination and electrical and magnetic influence induced by a degree of heat not nearly sufficient for ordinary direct rock-fusion, that consequently may exist at such a moderate depth as not to render impossible the passage of small ejections of the resulting lava through vents in the overlying rocks.

In other words, a moderate heat may induce where there are suitable materials and conditions such chemical and other action as will produce sufficient additional heat to cause rock-fusion, which will necessarily be confined to the region and the period where and when the suitable materials and conditions exist.

This hypothesis is founded on the doctrine that chemical reactions, favoured by fusion, may be restrained or prevented by a pressure that raises the fusion point of temperature, and that when the liquefaction of substances fusible at low temperatures is

effected, changes are initiated that will produce sufficient heat to fuse the more refractory substances with which they may be in contact; that, in fact, fluxes exist and operate in Nature's laboratory as well as in the furnaces of man.

I venture to think that this hypothesis fulfils the requirement of Sir Charles Lyell when he says in his 'Principles of Geology': "It is only necessary in order to explain the action of volcanoes to discover some cause which is capable of bringing about such a concentration of heat as may melt one after the other certain portions of the solid crust so as to form seas, lakes, or oceans of subterranean lava."

I am not prepared to deny, however, that water may be present, and, too, as an agent of reaction, where and when that chemical action commences which produces the greater heat that brings about rock-fusion; but after rock-fusion has commenced, and a lava source has been established, it cannot be possible for water in any form to approach such a source, in the ejection of the lava from which water can, therefore, have no part.

Nor is it easy to understand how water can act by its oxygen as an agent in a chemical reaction and still exist as water or steam. If the water has given up its oxygen to combine with bases, it can no longer be water, and only hydrogen will remain. The enormous volumes of steam given forth from explosive eruptions remain to be explained. True it is that MM. Fouqué reports considerable quantities of hydrogen as given forth from eruptions, but the amount is altogether insignificant when compared with that of the watery vapour, the whole of which being undecomposed has had nothing to do with any chemical reaction that may have taken place.

B. THE EJECTION OF LAVA FROM ITS SOURCE, AND ITS RISE IN A VOLCANIC TUBE OR CONDUIT, is due to the expansion caused by the change from the solid to the liquid state (comparable with the rise of mercury in the tube of a thermometer from increased bulk consequent upon increased liquidity), together with the production of potentially gaseous compounds, from chemical reactions amongst the many compounds forming, and accessory to, the mass of the magma, favoured by the fused condition.

This rise of the lava in the volcanic tube may be influenced by meteorological conditions, as the position of the top of the column of mercury in the tube of a barometer is affected by the weight of

the atmosphere, and the meteorological effect may be supplemented by lunar attractive influence. Thus it appears to me the lower or plutonic part of a volcanic tube is a thermometer and subsidiarily a barometer, and, if I may use a new word, an *helkusometer** (or measure of attractive influence) combined.

C. THE EXPLOSIVE FEATURES OF VOLCANIC ERUPTIONS I hold to be altogether secondary; and I consider these, as well as the determination of the position, and to some extent the distribution of volcanic vents to be due to the sea, the water from which, conveyed by interstitial percolation through cool, or not highly-heated, rocks, pours into the comparatively cool upper portion of fissures or old volcanic conduits together with ordinary land surface water.

This water, converted into steam by its descent to heated lower depths, and by the approach of ascending lava, causes by its expansive power the opening of rents, admitting large and sudden flows or gushes of sea-water to the lava conduit, which may have receptive expansions at but moderate depths where also water may have accumulated, and thus the conditions are produced that occasion the greater explosive effects of violent eruptions.

Simple emissions of lava without ashes or explosive phenomena are due to the absence of water except in small quantities, such as may be derived from the surface or from the rain or snow on crateral openings. The non-explosive, simply lava-emitting character of the Hawaian volcanoes is explained by their conduits being surrounded by water-excluding, because always highly-heated, though solid lava.

Purely explosive and ash eruptions are explained by the introduction of water into a fissure partly filled with lava which does not reach the top of the tube, and which by cooling and solidification if the fissure be a branch one, may effectually and permanently seal it and so prevent any further eruption at that point, as in the case of the single-eruption cratered ash-cones of the Phlegræan Fields. The actual volcano I consider to be due to the sea, which by giving its water in sufficient volume, when lava is ascending, produces that explosive and rending force which opens a vent at the surface and adds a volcano to the globe, and thus is explained that wonderful association of volcanoes with the sea that so markedly characterizes their distribution.

In the views here put forward it will be seen that the chemical

* From ἑλκυσίς—εως=attraction.

hypothesis is partly adopted, but associated with the relief given to vertical by tangential pressure. Both vertical pressure and superheated, or "potential," steam force as motive powers for the ejection of lavas from their sources are consequently discarded.

On some Bagshot Pebble-Beds and Pebble Gravel.

By Horace W. Monckton, F.G.S., and R. S. Herries, M.A., F.G.S.

(*Read January 4th*, 1889.)

No one who makes a careful study of that part of Essex included in Sheet 1 of the Geological Survey Drift Map can, we think, fail to be struck by the number and extent of beds which, though variously described as pebble-beds or gravels, have one feature in common, namely, that they are chiefly composed of chalk flints more or less worn, rounded, or broken. On the map these beds are assigned to five classes:—Bagshot Pebble-Beds, Pebble Gravel, Middle Glacial Gravel, Thames Valley Gravel, and gravel of doubtful age. Their precise age has, however, been a subject of considerable discussion, and the present paper is an attempt to deal with some of the questions which still remain unsettled.

The chief point to which we propose to direct attention is the relation between the beds classed as Bagshot pebble-beds and those named pebble gravel, and with a view to determine the right of any of them to be looked upon as beds of Eocene age we shall first consider some Bagshot pebble-beds in the Bagshot district, about the age of which there can be no question, and compare them with certain other deposits of pebbles in the same area.

In that district a well marked bed of pebbles usually, if not always, occurs at the base of the Upper Bagshot sands. It was well shown in a railway cutting near Ascot, where it is 10 inches thick and formed of a compact mass of well rolled flint pebbles, sometimes in iron-sand forming a hard conglomerate, at others in loose greenish sand.* It may now be studied in a railway cutting a little south of Wellington College Station, where the pebbles are not compactly bedded, but form two thin irregular lines in a loose greenish sand ('Quart. Journ. Geol. Soc.,' Vol. xliv p. 614, Fig. 10). In

* W. H. Herries, 'Geol. Mag.,' Dec. 2, Vol. viii, p. 171.

the Bracklesham beds of this district pebble-beds also occur, but are variable in thickness and not persistent.

The deep well-sections at the Albert Orphan Asylum and elsewhere satisfactorily prove that the basement pebble-bed of the Upper Bagshot and the Bracklesham pebble-beds are true Eocene beds, and with the exception of the Ascot well, where a few pebbles are said to have been found in the Lower Bagshot, there is no record of pebbles in these well-sections at any other horizon in the Bagshot beds.

The thickest pebble-beds recorded in these well-sections are three feet at Wellington College ('Quart. Journ. Geol. Soc.,' Vol. xli, p. 494), and three feet six inches at Farnborough, near Aldershot (*ibid.*), but it may be doubted whether these are compact masses of pebbles.

In the Lower Bagshot of the same district there are occasionally thin lines of pebbles ('Quart. Journ. Geol. Soc.,' Vol. xlii, p. 414), and at one place a more important pebble-bed appears to belong to that division of the Bagshot series. It is now well seen in a pit between Barkham and Bearwood Park, described by Dr. Irving.* There we have a compact mass, five feet thick, of pebbles, all of flint, mostly small, but some as much as three inches in diameter. The upper limit of the pebbles is a straight line cutting the slope of the hill, and above it are two feet or more of apparently undisturbed Bagshot sand with pipe-clay laminæ. The pebble-bed rests on brownish clays. Dr. Irving refers this to the basement bed of the Upper Bagshot or one of the pebble-beds in the upper part of the Bracklesham, an opinion in which we do not concur. We believe it to be a Lower Bagshot pebble-bed, but as the decision of this question does not affect our argument we will not go into it in the present paper.

The pebble-beds above described have the following characteristics:—They are composed almost wholly of flint pebbles, for with the exception of some quartz pebbles not more than one-fifth of an inch in diameter we have not found any other sort of pebble in them. They are conformable to the strata in which they occur and do not follow the contour of the surface of the ground. The example five feet thick at Bearwood is the thickest which we have seen, and they are usually very much thinner.

We think we have now dealt sufficiently with the beds which we

* 'Geol. Mag.,' Dec. 3, Vol. iv, p. 111; 'Quart. Journ. Geol. Soc.,' Vol. xliv, p. 176.

are prepared to admit to be Bagshot pebble-beds, and we pass on to consider certain beds of pebbles which we believe are not true Bagshot beds, but derived from them and redeposited at a later period.

It will generally be found that the surface of the ground for some distance from the outcrop of a pebble-bed in sandy or clayey strata is covered more or less with pebbles derived from the bed. A good example occurs at Park Hill, Croydon, which was visited by the Association in 1882.* There a large pebble-bed, 15 feet thick, crops out near the top of the hill, and the surface of the ground to the south of the outcrop is covered with an irregular deposit of pebbles, evidently the *débris* of portions of the pebble-bed which, together with the sandy strata in which it was imbedded, has been destroyed by denudation, the sandy and clayey portions of the beds having disappeared, and the pebbles having been left to form a new and irregular deposit along the present surface of the ground. We may cite, as another example, the pebble-bed near Wellington College, which we have already mentioned as cropping out in the cutting about a quarter of a mile south of the station. Pebbles, obviously from this bed, are found for a considerable distance to the north of the station, in some places forming a reconstructed pebble-bed some inches thick at the surface of the ground.

On the other hand, it is no doubt possible that in some cases where a pebble-bed occurs in sandy strata it may be sufficient to arrest denudation, and may thus be found still in its original position though forming the present surface of the ground. We may therefore expect to find :—

(1) Bagshot pebble-beds at the surface of the ground but little altered, where the pebbles have been sufficient to arrest denudation.

(2) The *débris* of Bagshot pebble-beds redeposited and forming a new pebble-bed at the surface of the ground.

In the first case it is quite possible that a certain amount of foreign material from drift gravels might find its way into the Bagshot pebble-bed now at the surface; and in the second case, if the surface of the ground happened to be free from drift, the new pebble-bed would contain no extraneous matter, and would in all probability greatly resemble the original Bagshot bed from which it was derived; but it would differ from it by its materials being deposited in a much more irregular manner.

* The section is described by Mr. Klaassen, 'Proc. Geol. Assoc.,' Vol. viii, p. 226.

Now all over the Bagshot country in the London Basin we find beds of pebbles usually on high ground, and in some cases these beds are called Bagshot pebble-beds, in others pebble gravel, or gravel of doubtful age, and the test usually applied appears to be, that if the bed consists entirely of flint pebbles it is Bagshot, but if it contains quartz, angular or subangular flints, or chert, it is not Bagshot. We cannot admit this test to be satisfactory; we think it quite possible, as we have already shown, that a true Bagshot bed, if at the surface, might have a few extraneous stones introduced into it, and we think it probable that in some instances Bagshot beds may have been destroyed and the pebbles which they contain formed into new pebble-beds with but a very small admixture of foreign material.

We now proceed to illustrate what we have said by examples. The bed of flint pebbles which, as we have already mentioned, marks the base of the Upper Bagshot, and a subordinate pebble-bed which in many cases occurs in the Bracklesham beds, crop out to the east of the line of hills which forms the chief mass of the Upper Bagshot sands in the Bagshot area, and they may easily be found at many places, between Pirbright and Ash, for instance. East of the outcrop we find the surface of the ground frequently covered with pebbles, as, for instance, Bullswater Common ("Cook's Heath" on the Geological Map), near Pirbright. It is a low plateau formed of the upper beds of the Bracklesham, cut off by valleys from the nearest Upper Bagshot; but no one, we think, could doubt that the pebbles which cover it were derived from the Upper Bagshot basement bed which once existed some three to ten feet above the present surface of the ground.

Still further east is the plateau of Hook Heath, also composed of Bracklesham beds, which are well shown in the adjoining Goldsworthy railway-cutting,* and divided by a deep valley from the Pirbright outlier of Upper Bagshot sand. The surface of the heath is covered with pebbles, and the nature of the deposit is well shown in a pit in a field a little to the west of Hook Hill Farm. The pit is four feet deep, and shows a mass of pebbles extending from the floor of the pit to the surface of the ground. Sometimes the pebbles form a fairly hard conglomerate in an iron-sand matrix. In some places they are roughly stratified with coarse iron sand; one iron-sand layer is four inches thick at one

* Described by Professor Prestwich, 'Quart. Journ. Geol. Soc.,' Vol. iii, p. 382, Fig. 3.

point. The larger pebbles are all flint; but there are many small quartz pebbles up to three-fifths of an inch diameter. These small quartz pebbles are most abundant near the surface. We also found a subangular flint over two inches long low down in the pit.

Now, though it is clear from the position of this pebble-bed on the top of a hill in which the whole of the Bracklesham beds are present, and just at the place where we should expect to find the basement pebble-bed of the Upper Bagshot, that the pebbles are derived from that basement bed, yet we have no doubt that the pebble-bed now existing is not a Bagshot bed, but consists of the reconstructed materials of the Bagshot bed with a very small admixture of extraneous matter. The thickness of the bed, four feet or more, the coarse iron-sand, and the subangular flint all point to this, and we consider this a good example of a Bagshot pebble-bed rearranged, but very slightly removed from its original position.

At St. Ann's Hill, near Chertsey, some seven miles north-east of Hook Heath, we find pebble-beds in great force apparently in and at the top of the Upper Bracklesham beds,* and the tops of intermediate hills near Botley's Park and Ottershaw are covered with numbers of pebbles. These hills are formed of the Bracklesham beds, and we think we are justified in assuming that the pebbles are the ruins of the pebble-beds which we should infer to have existed in the upper parts of the Bracklesham and at the base of the Upper Bagshot now removed by denudation. Assuming this to be admitted, we pass to the heath named Horsell Birch, which is situated on the Lower Bagshot sands between the Ottershaw hills and Hook Heath, and at a considerably lower level. Here numerous small pits, usually about three feet deep, show that the surface of the heath is formed of masses of pebbles irregularly resting on, in, or under green sandy clay. In one place we noticed a mass of pebbles two feet three inches thick, and close to it, at the same level, two feet of clay, with very few pebbles. We found two angular flints on the surface, and one quartz pebble two inches in diameter.

Now, bearing in mind that there is no pebble-bed at the base of the Bracklesham in this district, and that pebbles from the Upper Bagshot basement bed or Upper Bracklesham beds are found on

* At one time we expressed an opinion that there were pebbles in the Lower Bagshot here, but this was, we think, a mistake (see 'Q.J.G.S.,' Vol. xlii, p. 404).

the hills around, at Ottershaw, Chobham Place, Bisley, Knap Hill, and Hook Heath, we think it clear that the Horsell Birch bed is the remains of the pebble-beds at the base of the Upper Bagshot and in the upper beds of the Bracklesham, which formerly extended over this area, but have been removed by denudation, during the progress of which the pebbles were collected and deposited on the upper beds of the Lower Bagshot at Horsell Birch. There they have formed a deposit sufficiently substantial to arrest further denudation, so that the heath now stands somewhat above the shallow valleys cut by streams around it.

Large quantities of pebbles are found at the surface of the ground over the plateau west of Egham, on which Englefield Green and the new Holloway College are situated. This plateau is proved by several good sections to be composed of Lower Bagshot sand, which appears to be present in nearly its full thickness. The pebbles lie above this, not in it, and seem to follow the present surface of the ground. It may be noted, however, that there is a quite distinct pebble-bed in the Lower Bagshot Sands here (which may be seen in a sand-pit in the grounds of the Holloway College), but this is a mere line an inch thick, whereas the surface bed is of considerable thickness, being dug to mend the roads.

In the instances above referred to, the re-deposited beds contain little that may not have come from Bagshot beds; but this is not always the case. In the valley south-west of Virginia Water Station we find a gravel consisting of about equal proportions of pebbles and subangular flints. The pebbles are, we think, for the most part derived from the Bagshot beds and the subangular flints from the plateau gravels, which do not usually contain anything like so large a proportion of pebbles, the *débris* of the two deposits having been mingled during the process of redeposition.*

Though we might give other instances, we think we have said sufficient to show that pebble-beds occur in the Bagshots of the Bagshot district, and that considerable deposits of pebbles have in places been formed by re-deposition during the progress of the denudation which the Bagshot beds have undergone, and we now pass on to the Bagshots of Essex, where we hope to show that a similar process has been going on. In 1868 certain pebble-

* This gravel contains a few quartz pebbles about ½-inch diameter. There are good sections near Trumps Green.

beds in that county were described by Mr. S. V. Wood, jun. ('Q.J.G.S.,' Vol. xxiv, p. 465), and claimed by him as Bagshot beds. The Geological Survey has admitted the right of some of them to that title, but has named others pebble gravel.*

Mr. Wood claimed these beds as Bagshot mainly on the ground of their being always associated with the Bagshot sand; but this argument fails if the beds at Jack's Hill, High Beech, and Rayleigh are correctly mapped pebble-gravel and not Bagshot beds, and if those at Norton Heath and Galleywood, "which seem to rest directly on the London Clay" ('Mem. Geol. Surv.,' Vol. iv, p. 321), are Bagshot, and we are not very clear on what grounds these Essex pebble-beds are mapped Bagshot by the Geological Survey. The chief reason seems to be that at Langtons, near South Weald Park, some of the pebbles appear to be interbedded with the Bagshot sand, and we have, therefore, made a careful examination of that locality.

Langtons is on the southern spur of a small outlier of Bagshot sand, which is but slightly divided from the larger outlier of Kelvedon Common. There are on both outliers patches of pebbles, but so far as can be seen there is not a continuous deposit of pebbles conformable to the Bagshot sand.

The only good section is at Langtons, probably in the same pit, in which the section represented in the 'Memoirs of the Geological Survey' (Vol. iv, p. 324, Fig. 78) occurred, or very near it. The details are as follows:—

SECTIONS AT LANGTONS, SOUTH WEALD PARK, ESSEX.

North End of Pit.

1.	Earthy bed, full of pebbles, many on end; thickness variable. It is at this point	3ft. 0in.
2.	Sand, reddish yellow, rather coarse; bedding irregular, a very irregular-shaped mass of pebbles running through it in the upper part. Lower down many scattered pebbles. We noticed several subangular flints, one two inches long, and two chalk pebbles at the bottom	5ft. 0in.
3.	White and yellow sand, with a few large pebbles at the top	2ft. 6in.
		10ft. 6in.

* It has been suggested that these beds may be Lower or Middle Bagshot (Wood, 'Q.J.G.S.,' Vol. xxiv, p. 465), Pliocene (Wood, 'Q.J.G.S.,' Vol. xxxvi, p. 473), Lower Bagshot (Whitaker, 'Mem. Geol. Surv.,' Vol. iv), Middle Bagshot (Whitaker, 'Geology of London,' 4th edit., 1884, p. 55). In the following instances Mr. Wood's pebble-beds are mapped "Bagshot Pebble-Beds" by the Survey: Brentwood, Warley, Norton Heath,

South End of Pit.

1.	Earthy bed, with pebbles	3ft. 0in.
3.*a*	Dark yellow sand	2ft. 6in.
3.*b*	Yellow, evenly bedded sand	4ft. 6in.
		10ft. 0in.

Bed 1 in the above sections appears to us to be a surface bed containing *débris* of pebble-beds and of the Boulder Clay. Bed 2 is, we think, of older date, but not Bagshot, for we have never seen in the Bagshot district any bed of that age at all like it, nor have we found chalk pebbles or subangular flints of the shape, size, and appearance of those found five feet below the top of the so-called Bagshot bed, and eight feet below the surface of the ground mapped "Bagshot Pebble-Bed."

Bed 3 may be Bagshot sand, and, according to the section published by the Survey, there are some 10 feet of pebble-beds, with beds of iron-stone and pipe clay below the bottom of the section now exposed.* These beds may be of Bagshot age, and if they extend over the whole outlier we should have little hesitation in admitting that they are so. In any case, we wish to draw attention to their even and regular appearance, very different from the pebble-bed in our Bed 2.

At Navestockside there is a pit in a bed of pebbles (mapped "Bagshot Pebble-Bed"); at the cross-roads south of Brizes there is a pit showing three or four feet of pebbles in yellow irony sand (mapped "Bagshot Sand"); and close to Dudbrook there is another pit two feet deep, showing pebbles in very clayey sand with many subangular flints, broken flint pebbles, and small quartz pebbles ($\frac{1}{2}$ inch diameter), and in it we saw one chalk pebble.

These patches strongly remind us of those in the Bagshot district. Probably those at Langtons (our bed 2), Navestockside, and Brizes, are ruins of beds which have disappeared in process of denudation before the period of the Chalky Boulder Clay, and that at Lang-

Frierning, Parson's Spring Wood, Writtle Park Wood, Stock, Billericay, Bentley Mill, South Weald Park, Langtons, Havering, and Galleywood. The Survey add a patch on Mill Green Common. The following are instances of beds called Bagshot by Mr. Wood, but mapped "Pebble Gravel:" High Beech, Jack's Hill, Laindon Hill, and Rayleigh. Mr. Wood also gives Kelvedon Common as a locality for Bagshot pebble-beds, but they are not mapped there.

* Since this paper was read we have been informed by the workmen that there is a thick deposit of pebbles, such as is described in the Memoir, beneath the lowest beds which are now exposed.

tons (our bed 1) and Dudbrook a similiar deposit with *débris* of Glacial beds intermingled with *débris* of the earlier deposits.

Around Brentwood and Warley the pebble-beds are very extensive, and all appear to be at the present surface of the ground. The following examples are on the Warley plateau, all at nearly the same level :—

Section A.—At the north end of Holdens Wood, mapped "Bagshot Pebble-Bed."

Mass of pebbles closely packed together in most places, but sometimes in very coarse reddish yellow sand; a few quartz pebbles up to $\frac{2}{5}$ inch diameter. In one place there is enclosed in the pebble-bed a fairly even band of sand several yards in length, and rather over one foot thick. Thickness up to 10 feet exposed.

Section B.—Quarter of a mile south of Warley Barracks, mapped "Bagshot Pebble-Bed."

Yellow sand, a few pebbles at the surface, and running irregularly into the sand; no compact mass of pebbles. Three feet.

Section C. – Three furlongs east of Warley Barracks, mapped "Pebble Gravel."

Yellow clayey sand full of pebbles, mostly on end, with several angular flints, and many quartz pebbles up to $1\frac{1}{2}$ inches diameter. In one place a mass of blue and grey clay, full of fragments of flint.

Of the above sections, *A* is utterly unlike any Bagshot bed with which we are acquainted, and in no way resembles the lower part of the section at Langtons as described by the Survey, and *B* shows that the massive pebble-bed is not continuous over the plateau. The gravel *C* appears to consist of *débris* of the bed shown in Section *A* mixed with *débris* of Boulder Clay.

At Norton Heath, near Ongar, there is a good example of a gravel apparently formed of the *débris* of beds of very different ages (mapped "Gravel of doubtful age," resting on "Bagshot Pebble-Bed"). It consists of flint pebbles, mixed with which are several subangular flints, a few flints which have been very little rolled, and some large pieces of quartz, the whole in a yellowish sand.

Langdon, or Laindon Hill, visited by the Association last summer, is capped by a considerable deposit of pebbles resting on Bagshot sand. We did not notice anything but flint pebbles in the bed, but it has been to a great extent worked away, and sections at present are few.

Mill Green Common, between five and six miles south-west of Chelmsford, is the last Essex example which we propose to notice. It is a plateau, the top of which is covered by a sheet of pebbles, of no great thickness, we think. In the heaps of pebbles dug from the pits we noticed some subangular flints, and one piece of quartz 2½ inches long, but they may have come from the surface. The pebbles rest on Lower Bagshot sand, which is shown in a sand-pit a little south of the common, and below the level of the pebble-pits.

The section showed 1½ feet of clay overlying 6½ feet of nearly white micaceous sand, and in the sand we found a few casts of univalve shells, the first instance, we believe of any sign of fossils having been noticed in the Bagshot beds of Essex.

We might bring forward several more examples of sections in these pebble-beds (*e.g.*, Stock, Galleywood, and Billericay, each of which confirms our views), but we think those given will serve as a general description of the rest, and will be enough to illustrate the point which we wish to make. They form a series of deposits at the surface of the ground, following to a certain extent the contour of the surface, and not the bedding of the beds on which they rest. They cap hills, or form more or less irregular patches on plateaux, having served to protect the soft strata on which they rest from denudation. They sometimes consist almost entirely of flint pebbles, but sometimes contain quartz pebbles and subangular flints, and they generally show little sign of stratification. They, in many cases, appear to be older than the Boulder clay, but are probably not Middle Glacial gravels, for those beds are usually stratified, and contain abundance of quartz, quartzite, etc. We cannot, however, admit that they are of Bagshot age, nor do we think they were formed by marine action. We believe them to be the result of subaërial denudation, assisted in some cases, perhaps, by streams or small rivers, the materials being collected in hollows and valleys, which have now become hill tops, owing to the protection afforded by the pebbles.

The materials have, in all probability, been largely derived from the Bagshot beds, almost entirely so in such cases as the deposits at Holden's Wood and Langdon Hills, but in other cases with an admixture of *débris* of Glacial beds, as at Norton Heath.

The practical importance of distinguishing between such reconstructed beds as we have been describing and Bagshot pebble-beds

is well shown by an example from the Newbury district. The locality is Bussock Camp, on Snelsmore Common, about four miles north-west of Newbury. The Common forms a plateau, and the southern portion is covered by a deposit of gravel, composed of subangular flints and pebbles, etc., but at the northern end the hill is capped by a deposit of pebbles, which are in an earthy bed some two or three feet thick, and apparently rest on the London Clay, which is here very thin, as is proved by the occurrence of the large pebbles which mark the junction with the Woolwich and Reading beds, in an opening on the slope of the hill, only a few feet below the top. This deposit of pebbles has been claimed as a Bagshot bed (See Circular of March 17th, 1888, Excursion to Newbury, etc.); and, if this is the case, the London Clay has here thinned out to a few feet, a most interesting fact if true. But if, on the other hand, this deposit of pebbles is, as we believe, merely an instance of a bed formed by the *débris* of Eocene pebble-beds, then its presence affords no evidence of what the original thickness of the London Clay at this place may have been.

As to the age of these pebble deposits, we offer no definite opinion. The process of denudation and re-deposition has probably been going on ever since the Bagshot beds emerged from the sea in the areas with which we have dealt, and the ages of these patches may vary from that time to the present day; for wherever a pebble-bed crops out pebbles from it are gradually finding their way down to the valleys to form such deposits as those we have been examining. The bed of nearly every stream in the Bagshot district affords an example of such a deposit in process of formation. In conclusion, we think we have brought forward sufficient evidence to show that in many cases reconstructed beds have been confounded with those occurring as originally deposited, and that, on the other hand, it is not safe to say that a series of pebble deposits at the surface of the ground are of different character merely because they are formed of different materials, when it may be that the circumstances of their deposition have been precisely the same.

On the Palæontology of Sturgeons.

By A. Smith Woodward, F.G.S., F.Z.S., of the British Museum (Natural History).

The Acipenseroid Fishes, or the common Sturgeons and their allies, have been looked upon by naturalists ever with increasing interest as the minutiæ of their anatomy have been revealed and made the subject of comparative study. They are the links between cartilaginous fishes and those possessed of well-formed bones; and, such being the case, they are evidently the little modified descendants of a race dominant in very remote Palæozoic times. Their Palæontological History, if it could be fully deciphered, would thus be one of considerable significance in the discussion of the philosophical problems of Biology; and it is proposed on the present occasion briefly to review the few fragments of this history that are already available for consideration.

The members of the group existing at the present day are divisible only into four genera and two families,* and the most familiar genus, *Acipenser* (or the common Sturgeon), has the widest distribution and the greatest number of species. This fish, with its close ally, *Scaphirhynchus*, forms the family Acipenseridæ, characterized by the presence of five longitudinal series of bony scutes upon the trunk. The *Polyodon* (=*Spatularia*) of the Mississippi, and *Psephurus* of the Chinese rivers, form the family of Polyodontidæ, in which there are no large scutes upon the trunk, and only occasional small stellate ossifications.

An examination of *Acipenser* itself (Fig. 1) suffices to indicate the main characteristics of the order, so far as known. The roof and sides of the head are covered with dermal plates or membrane bones, and both these and the armature of the trunk have the microscopical structure of true bone, thus exhibiting an advance upon the dentinal dermal calcifications characteristic of Selachians and Chimæroids, and probably of some older groups. The cartilaginous cranium itself is almost entirely persistent, only two or three small lateral areas being converted

* A. Günther, 'Catal. Fishes British Museum,' Vol. viii (1870), pp. 332-347.



FIG. 1.—Skeleton of Sturgeon (*Acipenser*).

1, posterior extremity of cartilaginous cranium beneath the head-plates; 2, upper jaw; 3, hyomandibular bone; 4, lower jaw; 6, gill-arches; 8, pectoral arch; *a*, neural arches and spines, placed above the notochord; *b*, hæmal arches, placed below the notochord; *c*, dorsal fin; *e*, caudal fin; *f*, anal fin; *g*, pair of pelvic fins; *h*, pair of pectoral fins; *r*, ribs.

into bone,* and the base is covered with the well-known membrane-bone, the *parasphenoid*, besides representati *vomers*. The jaws are entirely suspended by the upper the hyoid arch, which here consists of two pieces instead as in the Selachii; and the uppermost of these sus elements, the *hyomandibular* (Fig. 1, 3) is considerably The two halves (*palato-pterygo-quadrate* cartilages) of th jaw (Fig. 1, 2) meet in the middle line in front Selachii, each half exhibiting two small tracts of oss and slightly overlapped by two apposed membrane-b *maxilla* and *jugal*.† Each half of the lower jaw (Fig. also mostly ensheathed in one large membrane-bone (' *tary*), with one of small size (*coronoid*, Parker). The bones are incomplete, and only one (the *operculum*) is d in the Sturgeon. In the figure, this element is rem display the branchial arches (6), of which there ar each side, and, like the *ceratohyals*, several of the car these are partially ossified.

In the axial skeleton of the trunk the notochord is p but there are cartilaginous neural arches and spines above this rod, and hæmal arches, more or less beneath.‡

The cartilaginous shoulder-girdle is entirely pers ensheathed in a series of membrane-bones (Fig. 1, most inferior element on each side is directed for named *interclavicle* or *infraclavicle;* the next is the *cla* is the *supraclavicle*, with a small *postclavicle* poste base, and this series is united to the hinder angle o shield on each side by still another element, the *pos*

The paired fins differ markedly from those of S approach those of higher Ganoids and Teleostei in

* W. K. Parker, "On the Structure and Development o Sturgeons," 'Phil. Trans.,' 1882, p. 176, Pl. xviii, Fig memoir (pp. 139-185, Pls. xii-xviii) is the most elabor treatise upon the skull of *Acipenser*. Figures are also given Hawkins' 'Atlas of Comparative Osteology' (1864), Pl. v, f

† This element is named *pre-operculum* by W. K. Par xviii, Fig. 5, but seems more probably homologous with t H. Traquair, 'Geol. Mag.' [3], Vol. iv, 1887, p. 253).

‡ R. Owen, 'Anatomy of Vertebrates,' Vol. i (1866), p. 3

§ W. K. Parker, "Monograph on the Structure and Dev Shoulder-girdle and Sternum in the Vertebrata" ('Ray Soc 10-14, Pl. i, Figs. 6-8. In this memoir the supraclavicle temporal, and the postclavicle, supraclavicle.

aracterize the weapons of
(Fig. 3*a*) there is a deep
dually widened towards
tion; and the anterior
lightly wavy edge, with
unabraded specimens,
The lateral ornamenta-
lar longitudinal rugæ,
expansions; and these
proximal extremity of
out any anterior keel,
perfect
large preaxial pectoral
a. they are found to
hey may, therefore, be
Acipenseroid fish, and,
cally assigned to the

Suffolk (Reed Coll.,
evidence of *Acipenser*
described by Leidy*
me of *A. oratus*.
re completely known
described, both the
discovered. It is
distinct scales upon
name of *Crossopholis*
being *C. magnicau-*
bones are very similar
relatively shorter, and
that of *Psephurus*. The
et dorsal and anal fins,
commencing slightly in ad-
re numerous, in oblique series,
consists of a small subquadrate

ta of the Western Territories" (Rep.
Pt. i, 1873), p. 359, Pl. xxxii, Fig. 58. The
s from the Molasse of Württemberg, described
s," 1882, p. 116, Pl. ii) are truly Selachian (K.
Akad. Wiss., 1886, Pt. 3, pp. 9-12).
n p. 28.

(Pl. I, Fig. 2); and Cope* has discovered a fish only generically distinguishable from *Polyodon* in the Eocene Green River Shales of Wyoming, U.S.A.

The London Clay fossils have not hitherto been described and figured, but there is a small series in the British Museum, and one scute is shown, of the natural size, in Pl. I, Fig. 1. The narrow, smooth, overlapped area is indicated, and the exposed portion exhibits the characteristic pitted ornament. The form, so far as recognizable, also corresponds with that of one of the dorsal scutes of an existing *Acipenser*. It is quite impossible, however, to found upon a series of isolated fossils of this kind a scientifically-defined species; though it will be convenient, for reference, to adopt Agassiz' provisional name of *Acipenser toliapicus*.

The detached scute from the Hempstead Beds (Pl. I, Fig. 2) also pertains to a fish of about the same dimensions as the Sheppey species, and exhibits all the features observed in a lateral scute of some existing forms.

The fossils just noticed being so precisely similar to the corresponding parts of the living *Acipenser*, we approach, with all the more satisfaction, the discussion of some problematical fish-spines, which do not appear to have been hitherto determined, and are in some respects suggestive of Siluroids and Scleroderm *Plectognathi*. So far as I have been able to discover, only one figure of such a fossil has been published,† the specimen being derived from the Lower Pliocene of Montpellier, France; but a few examples are now preserved in the British Museum from the Upper Eocene of the Hampshire Basin, and still finer specimens occur in the Reed Collection in the York Museum.

Through the kindness of William Reed, Esq., F.G.S., we are able to append figures of one of the last-named specimens (Pl. I, Figs. 3, 3*a*).

The fossils in question are stout unsymmetrical spines, evidently originally occurring in pairs, and showing no trace of

* E. D. Cope, "A new Chondrostean from the Eocene," 'Amer. Nat.,' Vol. xvii (1883), p. 1152; "Eocene Paddle-fish," *ibid.*, Vol. xix (1885), p. 1090; "On two New Forms of Polyodont and Gonorhynchid Fishes from the Eocene of the Rocky Mountains," 'Mem. Nat. Acad. Sci.,' Vol. iii (1886), pp. 161-163, Figs. 1-3.

† '*Premier rayon de la dorsale d'un Poisson, ayant quelque rapport avec celui des Balistes.*' P. Gervais, "Zoologie et Paléontologie françaises" (1852), 'Explic. Planches, Poiss. foss.,' p. 5, Pl. lxviii, Fig. 33.

proximal articular facettes, such as characterize the weapons of File-fishes and Siluroids. Posteriorly (Fig. 3*a*) there is a deep longitudinal groove, which becomes gradually widened towards the base, forming an extensive excavation; and the anterior border is compressed into a sharp and slightly wavy edge, with no denticles, but marked on each side, in unabraded specimens, with a series of small transverse striæ. The lateral ornamentation consists of a number of strong, irregular longitudinal rugæ, often raised at intervals into little nodose expansions; and these terminate at a short distance from the proximal extremity of the spine, thus leaving a smooth area, without any anterior keel, evidently more or less saddle-shaped when perfect

On comparing these spines with the large preaxial pectoral fin-ray of the common existing Sturgeon, they are found to agree in the most minute particulars. They may, therefore, be regarded as undoubtedly referable to an Acipenseroid fish, and, like the Sheppey scutes, may be provisionally assigned to the genus *Acipenser* itself.

Similar spines occur in the Red Crag of Suffolk (Reed Coll., York Museum); but the only other known evidence of *Acipenser* in beds above the Eocene is a typical scute described by Leidy* from the Miocene of Virginia, under the name of *A. ornatus*.

Prof. Cope's Eocene Polyodont fish is more completely known than the European *Acipenser*-like fossils just described, both the head and the caudal region having been discovered. It is remarkable on account of the presence of distinct scales upon the trunk, and has received the generic name of *Crossopholis* (fringe-scale), the single known species being *C. magnicaudatus*.† In many respects the cranial bones are very similar to those of *Polyodon*, but the snout is relatively shorter, and more closely corresponds in form to that of *Psephurus*. The body is long and slender, with short dorsal and anal fins, remotely situated, and the former commencing slightly in advance of the latter. The scales are numerous, in oblique series, not quite in contact; and each consists of a small subquadrate

* J. Leidy, "Extinct Vertebrata of the Western Territories" ('Rep. U.S. Geol. Surv. Territ.,' Vol. i, Pt. i, 1873), p. 350, Pl. xxxii, Fig. 58. The supposed Acipenseroid scutes from the Molasse of Würtemberg, described by J. Probst ('Württ. Jahresh.,' 1882, p. 116, Pl. ii) are truly Selachian (K. A. von Zittel, Sitzungsb. k. bay. Akad. Wiss., 1886, Pt. ii, pp. 9-12).

† See references in footnote on p. 28.

disc, with a row of long, sharp, backwardly-directed spines arranged upon the posterior margin. In an individual measuring 0·170 m. from the anterior extremity of the dorsal fin to the notch of the caudal, the scales only measure one millimetre each way; the caudal fulcra are large and strong.

Below the Eocene, no satisfactory evidence of Acipenseroid fishes has hitherto been recorded from deposits later than the Lias*; and on this horizon, as might be expected, some of the forms exhibit a greater divergence from the existing family and generic types than is observed in the Eocene examples.

On the present occasion, however, it is interesting to be able to add that some slight traces of the order are gradually becoming revealed among the fossils of our English chalk. Since the reading of my paper last Session, I have succeeded in interpreting some specimens in the British Museum, which have long been among the most perplexing of undetermined chalk fossils; and these must undoubtedly be regarded as forming part of a typical Acipenseroid tail.

The specimens in question are three small blocks of chalk from the Upper Chalk of Gravesend, Kent, exhibiting five more or less fragmentary fulcral scales, and portions of robust fin-rays, probably all found together, and belonging to the tail of one individual. They are numbered 33221-4, and drawings are given in Pl. I, Figs. 4, 5.

One of the fulcral scales is shown of the natural size in Pl. I, Fig. 4, the bifurcating inserted portion being restored in outline from another specimen. A still larger example, however, measures 0·024 m. in maximum breadth, and 0·027 m. from the apex to the bifurcation of the base. These scales are all deeply-overlapping, relatively broad, and notably flat; and the backwardly-directed apex is rounded and obtuse. The small exposed portion is ornamented with thick ganoine in irregular dots and short wavy lines, more or less clustered, especially near the margin.

Like the fulcral scales, the caudal fin-rays (Pl. I, Fig. 5) are also very robust, and the superficial ganoine thick and rugose, not always completely covering the exposed faces of the successive joints. As usual, each ray is double, and for some dis-

* The tail from the Cretaceous of Mount Lebanon named "*Chondrosteus ?*" by J. W. Davis ('Trans. Roy. Dublin Soc.' [2], Vol. iii, p. 501, Pl. xxiv, Fig. 1) is truly Teleostean.

tance proximally it is not articulated; when reached, however, the articulations immediately become very numerous and approximated, the divisions being mostly shorter than broad.

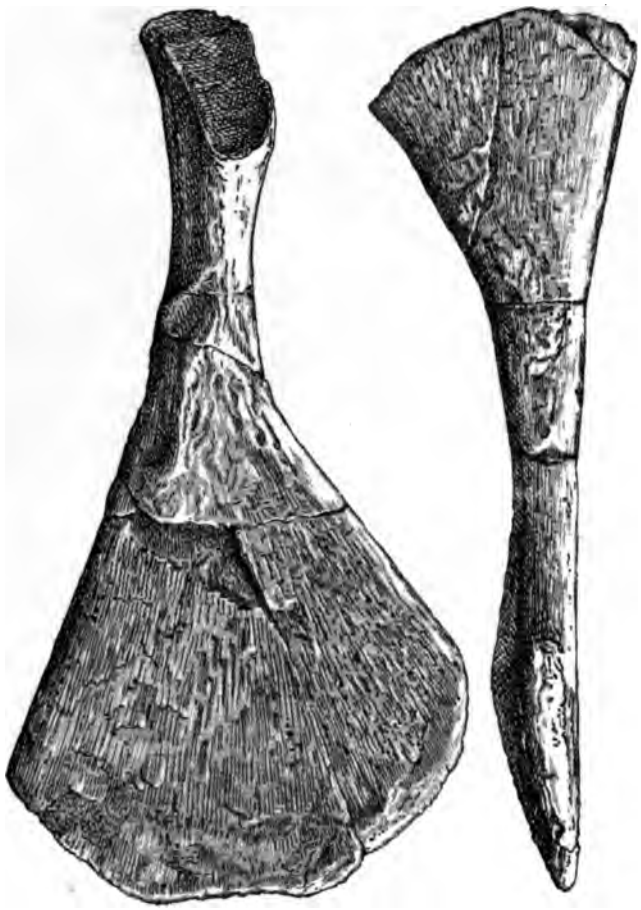
No oat-shaped scales, such as might have covered the sides of the upper lobe of the tail, can be distinguished; and, although the British Museum collection comprises undetermined dermal bones from the Chalk, nothing appears to be referable with much probability to an Acipenseroid of the same character.

In the Willett collection at Brighton, however, there is the extremity of a snout, from the Chalk of Sussex, which exhibits so much superficial resemblance to that of the common *Acipenser* that it may quite possibly belong at least to the same order (Pl. I, Figs. 6, 6*a*). This fossil is merely an imperfect example of thin sculptured bone enveloping the termination of the snout, and it only seems to differ from the corresponding armature of *Acipenser* in the fact that it is very broad, shows no sutures, and overlaps the margin more completely. It is ornamented above (Pl. I, Fig. 6) by large, coarse, forwardly-directed rugæ, passing into a network in front; the anterior face of the overturned margin is more or less smooth, apparently by wear; and the narrow inferior face of this margin is finely reticulated.

The Cretaceous caudal fulcra (or ridge-scales) most closely resemble those of *Psephurus* among living Acipenseroids; but they are broader and flatter, less pointed, and evidently betoken a stout depressed fish. Mr. Willett's fossil might thus belong to the same form, and the genus would be well distinguished; but, in any case, it will be convenient to propose for the British Museum specimens a provisional name, and record them as *Pholidurus disjectus*.

There is some reason to hope that before long evidence of other Acipenseroids will also be definitely recognized in later Jurassic rocks. In the collection of Oxford Clay Vertebrates made by Alfred N. Leeds, Esq., of Eyebury, Peterborough, there are traces of a very large fish, having stiff branched fin-rays and irregular dermal bones; and these fossils are apparently most nearly paralleled by Acipenseroids, though no elements sufficiently like those of known genera have yet been found to render any determination certain.

In the Upper Lias of the neighbourhood of Whitby, Yorkshire, however, fragments of the skeleton of a very large fish of this order have long been known. They were briefly noticed (not described) by Agassiz,* who assigned them to the "Cœlacanths," under the name of *Gyrosteus mirabilis;* and there are many fine specimens in the British Museum, besides



a. *b.*

FIG. 2.—Right hyomandibular bone of *Gyrosteus mirabilis*, lateral aspect (*a*) and posterior aspect (*b*); one-third nat. size. (B.M., No. P. 3356*a*.)

* L. Agassiz, *tom. cit.*, Pt. ii, p. 179. Some desultory notes have subsequently been published by Prof. J. F. Blake in Tate and Blake, 'The Yorkshire Lias' (1876), p. 256, Pl. ii, Figs. 2, 3.

others at York and Whitby. The cartilaginous skull seems to have been no more ossified than in the living genera, and the membrane bones do not form any extensive buckler. The hyomandibular element (Figs. 2, *a*, *b*)* is as robust as that of *Acipenser*, and similar in form, the small upper portion being compressed antero-posteriorly, and the large lower portion laterally;

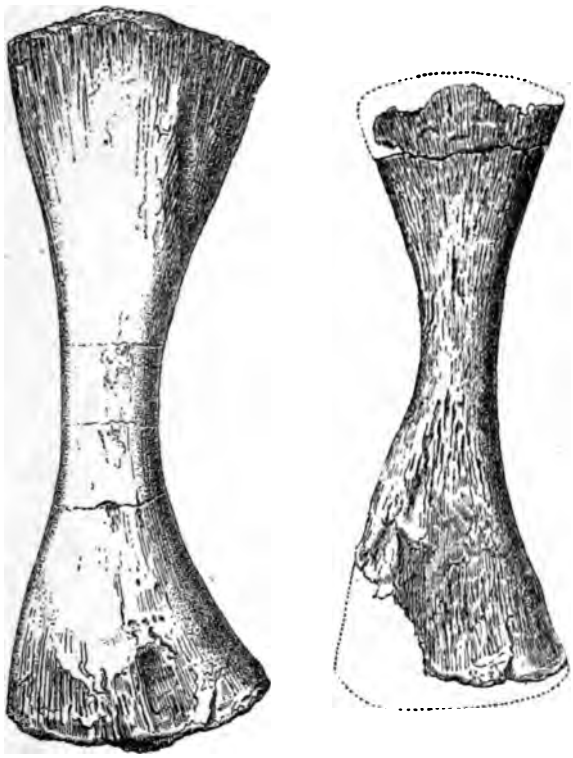


FIG. 3.—Ceratohyal bone of *Gyrosteus mirabilis;* one-third nat. size. (B.M., Nos. P. 2262, 43304.)

but in the adult there is a greater extension of the ossification, almost or quite the whole of the lower expanded portion being bony, whereas in *Acipenser* the cartilage persists. One or two membrane bones are noticeable in the region of the jaws,† but

* "? humerus" of Blake, *op. cit.*

† Since the reading of the paper, Mr. Martin Simpson has kindly shown me an interesting bone in the Whitby Museum (No. 338), very suggestive of a well-developed parasphenoid. It is not quite bilaterally symmetrical in every minor feature, but appears approximately so in general outline.

Fig. 4.

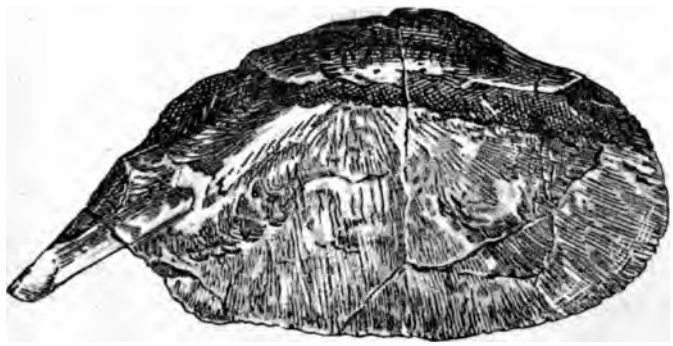


Fig. 5.



Fig. 6.



Fig. 4.—Left clavicle of *Gyrosteus mirabilis*, outer aspect; one-sixth nat. size. (B.M., No. 3356.)
Fig. 5.—Left clavicle of the recent *Acipenser*, outer aspect; reduced.
Fig. 6.—Right supraclavicle of *Gyrosteus mirabilis*, inner aspect; one-sixth nat. size. (B.M., No. 3356 *b*.)

there are no teeth. The ceratohyal cartilages (Fig. 3) are ossified and hour-glass-shaped, as in the living genera; and several smaller bony bars seem to indicate partial ossification of the branchial arches. There is at least one large membrane bone in the opercular fold, this corresponding either to the operculum of *Acipenser*, or to the sub-operculum of *Chondrosteus;*

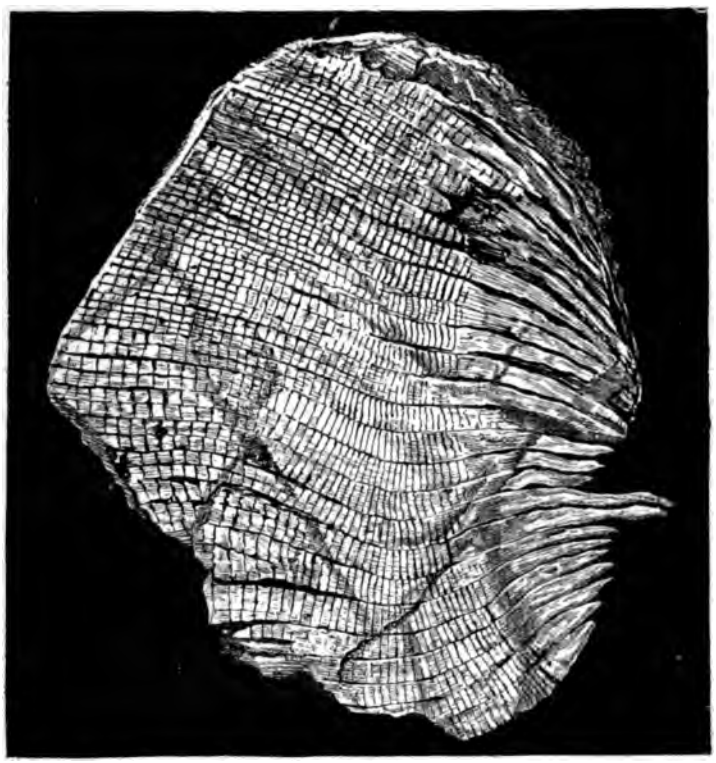


FIG. 7.—Caudal fin-rays of *Gyrosteus mirabilis*; one-third nat. size. (B.M., No. P. 3356*c*.)

and I have observed no indications of branchiostegal rays. The notochord must have been persistent, and a few slender bones in the anterior portion of the trunk may be interpreted as ossified ribs, like those of *Acipenser*. A membrane-bone of the shoulder-girdle, evidently to be regarded as clavicle (Fig. 4), is also much like the corresponding element (Fig. 5) in the living

genus just mentioned, its inferior portion being more produced forwards than that of the Lower Liassic genus, *Chondrosteus;* but there is no ornamentation or ganoine upon the external portion. The foremost rays of the pectoral fin are not articulated;* but in those rays where articulations do occur they are closely set and numerous. The superior margin of the upper lobe of the tail is ridged with large fulcra, as shown by a specimen in the York Museum;† and all the caudal fin-rays are closely articulated except for a short space proximally (Fig. 7). The trunk seems to have been destitute of scales and dermal ossifications; and I have not observed any scales assignable to the sides of the caudal lobe.

So far as determinable, the parts of *Gyrosteus* thus agree well with those of modern Acipenseroids, and the only attempt at a generic definition that can yet be made is as follows:—Head with few membrane bones, none externally ornamented or covered with ganoine; jaws toothless. Membrane bones of pectoral arch unornamented, without ganoine; preaxial pectoral fin-rays not articulated. Body naked; caudal lobe with a superior series of large flattened fulcra. Ossified ribs present. The single known species, *G. mirabilis*, attains a very large size, probably not measuring less than six or seven metres in total length.

The Acipenseroid genus of the Lower Lias—*Chondrosteus*—displays many striking differences from *Gyrosteus* and the more modern genera, and is a comparatively small fish, perhaps rarely exceeding one metre in length.‡ This genus, also, was first recognized and named by Agassiz,§ who met with portions of the tail among fossils from the Lias of Lyme Regis. It was

* A specimen in the collection of Mr. S. Chadwick, F.G.S., Malton Museum, seems to exhibit the minute superficial asperities so characteristic of the pectoral fin of *Chondrosteus*.

† Since the reading of the paper I have been able, through the kindness of Mr. H. M. Platnauer, B.Sc., to re-examine this specimen. In form, the scutes are very similar to those of *Chondrosteus*, but there is no external layer of ganoine, and the only traces of ornamentation are feeble rugæ upon the exposed sides. The largest scute measures 0·11 m. from the basal bifurcation to the apex; but in the collection of Mr. S. Chadwick, F.G.S., Malton Museum, there are portions of two tails of *Gyrosteus* of much smaller size.

‡ An imperfect specimen in the British Museum (No. 28714) is of twice the ordinary size.

§ L. Agassiz, *tom. cit.*, Pt. ii, p. 280.

first described by Sir Philip Egerton in 1858,* and subsequent contributions to our knowledge of its skeleton have been made

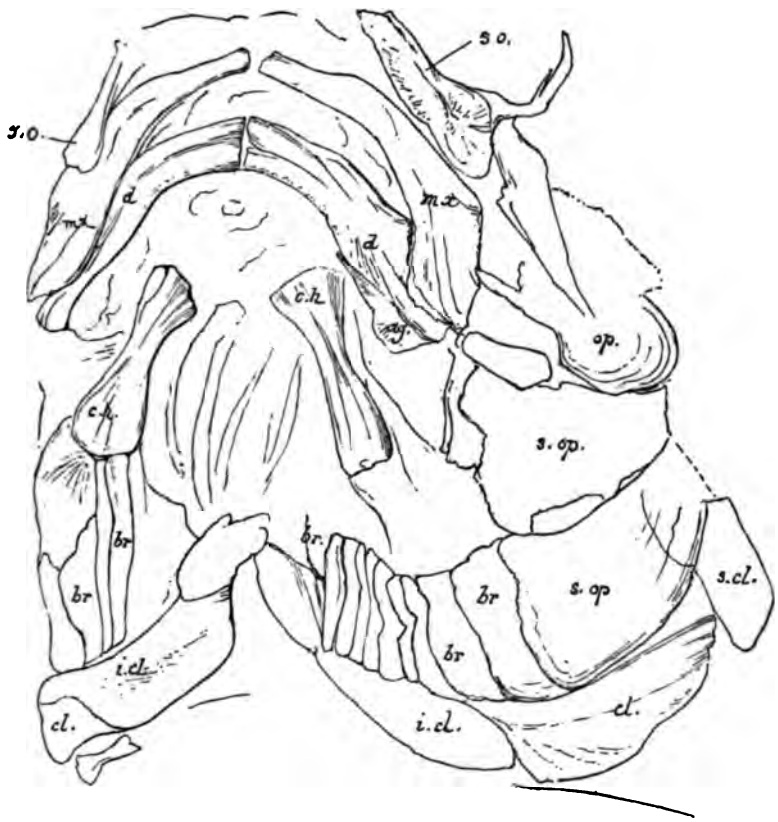


FIG. 8.—Head of *Chondrosteus acipenseroides*, seen obliquely from below; somewhat reduced (after Traquair). (B.M., No. P. 2048.)

Key to lettering of Figs. 8, 9.—*ag.*, angular; *br.*, branchiostegal rays; *c.b.*, cerato-branchial; *c.h.*, cerato-hyal; *cl.*, clavicle; *d.*, dentary; *f*, frontal; *hm.*, hyomandibular; *i.cl.*, infraclavicle; *m.pt.*, mesopterygoid; *mx.*, maxilla; *op.*, operculum; *pa.sph.*, parasphenoid; *pcl.*, postclavicle; *pt.*, palatine; *pt.f.*, post-frontal; *s.cl.*, supraclavicle; *s.o.*, suborbital; *s.op.*, suboperculum; *sq.*, squamosal.

* Sir P. Egerton, "On *Chondrosteus*, an extinct genus of the Sturionidæ, found in the Lias Formation at Lyme Regis," 'Phil. Trans.,' 1858, pp. 871-885, Pls. lxvii-lxx.



FIG. 9.—Head of *Chondrosteus acipenseroides* (after Traquair). (B.M., No. P. 2049.)

by J. Young,* J. W. Davis,† and R. H. Traquair.‡ Two species, *C. acipenseroides* and *C. crassus*, were distinguished by Egerton; but Davis has proposed, upon present evidence, to recognize but a single one—the first.

The jaws of *Chondrosteus* are much like those of *Acipenser*, and similarly toothless; but the membrane bones of the cranial

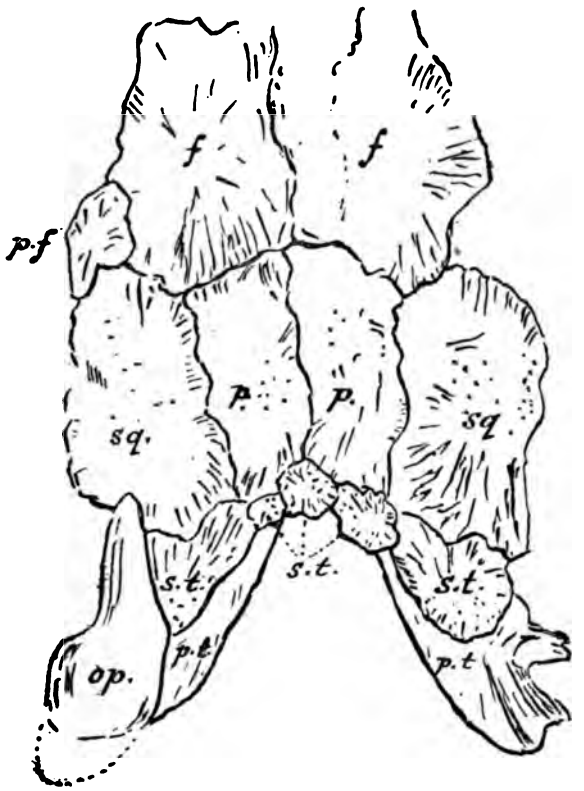


FIG. 10.—Cranial shield of *Chondrosteus acipenseroides*; somewhat reduced (after Traquair). (Mus. Practical Geology.) *f.*, frontal; *op.*, operculum; *p.*, parietal; *p.f.*, post-frontal; *p.t.*, post-temporal; *s.t.*, supra-temporal; *sq.*, squamosal.

* J. Young, "On the Affinities of *Chondrosteus*, Ag.," 'Quart. Journ. Geol. Soc.,' Vol. xxii (1866), p. 596 (abstract only).

† J. W. Davis, "On *Chondrosteus acipenseroides*, Agassiz," 'Quart. Journ. Geol. Soc.,' Vol. xliii (1887), pp. 605-616, Pl. xxiii.

‡ R. H. Traquair, "Notes on *Chondrosteus acipenseroides*, Agassiz," 'Geol. Mag.' [3], Vol. iv (1887), pp. 248-257, with figures.

roof (Fig. 10), so far as known, are very different, ordinary parietals and frontals being distinguishable, with a well-marked chain of supra-temporal bones, and the post-temporal element moveably articulated. The opercular membrane is also remarkable for the number of its supporting bones, there being a small operculum, a very large sub-operculum, and a few branchiostegal rays. The notochord must have been persistent, and the neural and hæmal arches resemble those of modern Sturgeons, but there are apparently no ribs. In the pectoral arch, the clavicle is scarcely bent forwards inferiorly, and the infraclavicle is very prominent. The anterior rays of the pectoral fins are unjointed, but there is no very robust spine; the pelvic fins are supported each by a single series of stout basal cartilages (perhaps partly ossified), much fewer in number than the fin-rays; the dorsal fin is

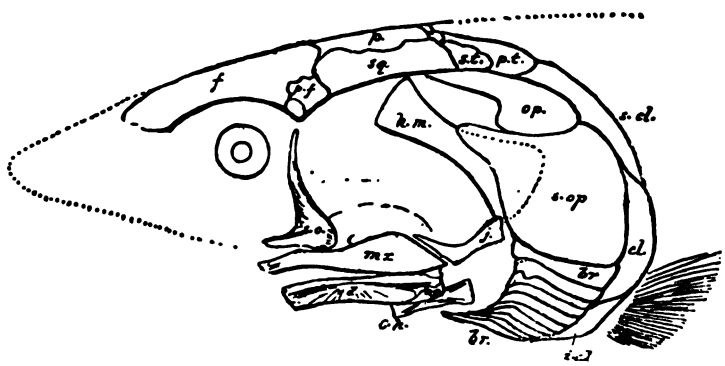


FIG. 11.—Profile of head of *Chondrosteus acipenseroides*, restored (after Traquair.) Letters as in Figs. 8-10. *j.* jugal.

opposite the pelvics, and the anal fin is remotely placed, near the caudal. The upper lobe of the tail has a ridge of large fulcra (Pl. I, Fig. 7), and the fin is deeply forked. There are no traces of scales or ossifications upon the trunk; but the sides of the caudal lobe are covered with elongated diamond-shaped or oat-shaped scales.

The accompanying restoration (Fig. 12) has been carefully drawn, of one-sixth the natural size, by Mr. Charles Berjeau, F.L.S.; the head being mainly a copy of Dr. Traquair's outline-sketch, the form and proportions of the trunk and fins being almost exactly as in a fine specimen in the British Museum

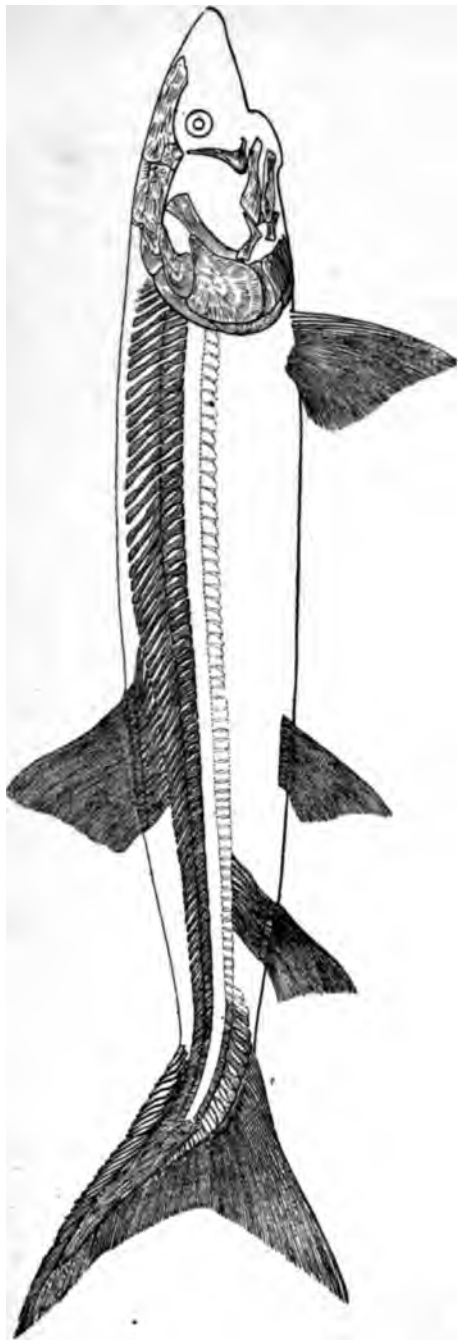


FIG. 12.—Restoration of skeleton of *Chondrosteus acipenseroides*; one-sixth nat. size.

(No. P. 3366), and the proportions of the neural arches in the abdominal region being taken from Davis' figure in the Geological Society's Journal.

As pointed out by Dr. Traquair (*loc. cit.*), the characters in which *Chondrosteus* differs most remarkably from the modern Acipenseroids are such as suggest close affinity with the great extinct tribe of Palæoniscidæ. On comparing *Chondrosteus* with the latter the cranial shield will be found to be very similar; the aspect of the opercular and branchiostegal apparatus is almost the same, "although in *Chondrosteus* there is no preoperculum, and the series of branchiostegal rays of the two sides may not have met in the middle. The special resemblance of the shoulder-girdle to that of *Palæoniscus* is also very striking, especially in the form of the post-temporal and supra-clavicular bones."

The same conclusions as to the Acipenseroid affinities of *Palæoniscus* and its allies were also elaborately formulated by Dr. Traquair in his memoir on the Palæoniscidæ,* written at a time when the osteology of *Chondrosteus* was much less completely known than at present; and it may be that, as no ordinary Sturgeons or Polyodons have been found in Palæozoic rocks,† their early forerunners are truly to be recognized in the great Palæoniscid group. These fishes, indeed (Fig. 13), have

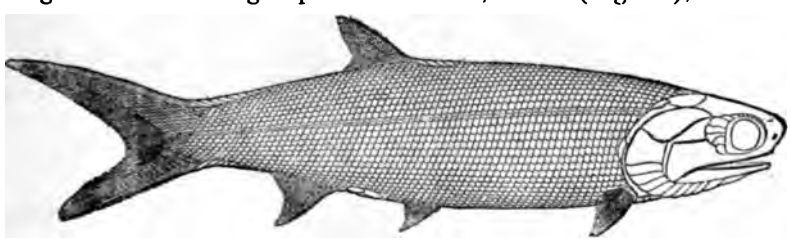


FIG. 13.—Restoration of *Palæoniscus* (after Traquair).

a strongly heterocercal tail with large fulcra; the dermal rays of the median fins are more numerous than the supporting interspinous bones; the pectoral arch possesses a pair of infraclavicular bones; and, in the more specialized forms, the general similarity in the aspect of the head is very striking. Moreover, although most genera have a well-developed squamation, a few

* R. H. Traquair, "The Palæoniscidæ," 'Mon. Pal. Soc.,' 1876, pp. 34-42.

† *Macropetalichthys* (J. S. Newberry, "Geological Survey of Ohio," Vol. i, Pt. ii, 'Palæontology,' 1873, p. 290), from the Devonian of the United States and Europe, seems truly a "Placoderm," though sometimes doubtfully associated with the Acipenseroids.

are either as destitute of scales upon the trunk as the existing *Polyodon*,* or at least possess scales of extreme tenuity.†

Whether the Palæoniscids be included in a division of fishes named "Acipenseroidei" or not, there can thus be no doubt as to the close relationship existing between the characteristically Palæozoic and later types under comparison. But it must be remembered at the same time that there are also links between *Palæoniscus* and the more typical scaly "ganoids" of Mesozoic date. Such, for example, are the Triassic *Dictyopyge*‡ and *Catopterus*.§ In both these fishes the tail is semi-heterocercal; if Dinkel's figures are reliable, the rays of the median fins in the former genus are more numerous than the interspinous bones; the head is certainly more Palæoniscid in aspect than is shown in some restorations; and I have recently observed very suggestive traces of an infraclavicular element in the pectoral arch.

If the facts of Palæichthyology are sufficiently known to justify any broad conclusions, it would thus appear that Palæozoic fishes upon the biological level of the Palæoniscidæ have been succeeded in later times by two series modified in widely different directions. In the one direction there has been an advance through the bony ganoids towards the specialized modern types of fishes; in the other direction the only advance has been in the matter of size, and this accompanied by a certain amount of degeneration, culminating in Acipenseroids proper.‖

* *Phanerosteon*, R. H. Traquair, "Report on Fossil Fishes collected by the Geological Survey of Scotland in Eskdale and Liddesdale," Pt. i, Ganoidei, 'Trans. Roy. Soc. Edinb.,' Vol. xxx, 1881, pp. 39-43, Pl. iii, Figs. 6-8.

† *Actinophorus*, J. S. Newberry, "On the Fossil Fishes of the Erie Shale of Ohio," 'Trans. New York Acad. Sci.,' Vol. vii (1888), No. 7.

‡ Sir P. Egerton in Sir Charles Lyell, "On the Structure and Probable Age of the Coal-Field of the James River near Richmond, Virginia," 'Quart. Journ. Geol. Soc.,' Vol. iii (1847), p. 276. See also R. H. Traquair, "On the Agassizian Genera *Amblypterus*, *Palæoniscus*, *Gyrolepis*, and *Pygopterus*," 'Quart. Journ. Geol. Soc.,' Vol. xxxiii (1877), pp. 565-567.

§ J. H. Redfield, 'Ann. Lyc. Nat. Hist. New York,' Vol. iv (1848), pp. 35-40, Pl. i.

‖ In Prof. E. D. Cope's latest classification ('Amer. Naturalist,' 1887, p. 1018), the first of these conclusions is adopted; but, on the assumption that the basal cartilages (*baseosts*) of the pelvic fin in Palæoniscidæ were minute or absent, the Sturgeons are placed lower in the series than the latter. Under any circumstances the relative development of a single structural feature is a slight point for the distinction of two "super-orders"; and if "Podopterygia" and "Actinopterygia" are to hold separate rank, the Palæoniscidæ (so far as all positive evidence is concerned) may be as justly placed in the former as in the latter.

EXPLANATION OF PLATE I.

FIG. 1.—*Acipenser toliapicus*, Ag.; dorsal scute, outer aspect. London Clay; Isle of Sheppey. (B.M., No. P. 3372.)

FIG. 2.—*Acipenser*, sp.; lateral scute, outer aspect. Hempstead Beds; Isle of Wight. (B.M., No. P. 5283.)

FIG. 3.—*Acipenser*, sp.; pectoral spine, lateral aspect. Hempstead Beds; Isle of Wight. (Reed Collection, York Museum.)

FIG. 3*a*.—Posterior aspect of the same specimen.

FIG. 3*b*.—Three tuberculated superficial ridges of a similar fossil, four times nat. size. Upper Eocene; Isle of Wight. (B.M., No. 1533*a*.)

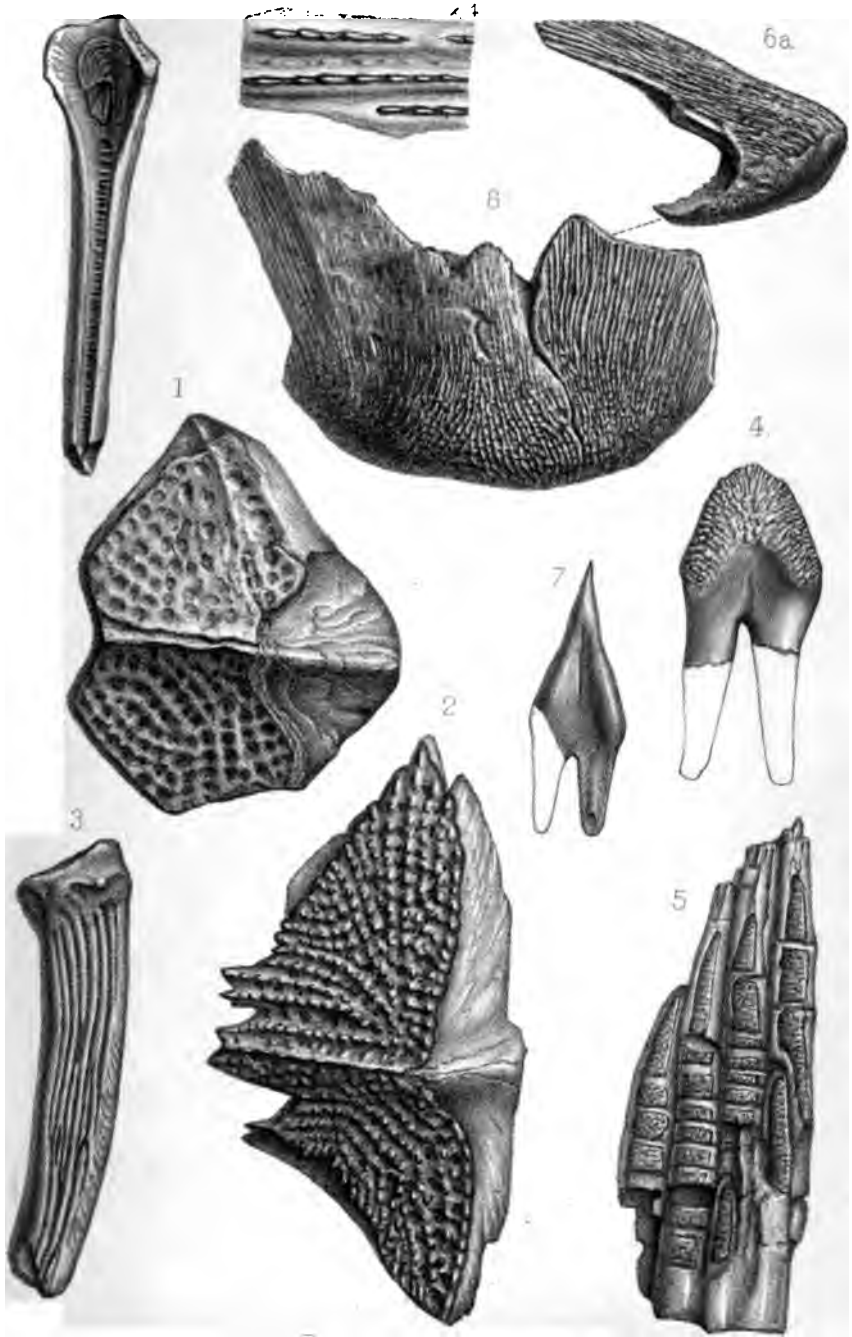
FIGS. 4, 5.—*Pholidurus disjectus*, gen. et sp. nov.; caudal fulcral scute, superior aspect, and associated fin-rays. Upper Chalk; Gravesend. (B.M., Nos. 33221, 33224.)

FIG. 6.—Extremity of snout, probably of an Acipenseroid Fish; superior aspect. 6*a*.—Ditto; lateral aspect. Chalk; Sussex. (Willett Collection, Brighton Museum.)

FIG. 7.—*Chondrosteus acipenseroides*, Ag.; caudal fulcral scute, superior aspect. Lower Lias; Lyme Regis. (B.M., No. 39495.)

Unless otherwise stated, the figures are of the natural size.

Postscript.—Since the foregoing paper was in type Mr. Montague Browne, F.Z.S., has kindly favoured the writer with the opportunity of examining some of the vertebrate fossils in the Leicester Museum. Among these may be noted the caudal region of a species of *Chondrosteus*, obtained by Mr. Browne from the Lower Lias of Barrow-on-Soar, being the first definite evidence of the genus from any locality other than Lyme Regis.



Fossil Sturgeons.

Berjeau & Highley del et. lith

Imp. Camb. Sci. Inst

Some Observations upon the Mode of Occurrence and the Genesis of Metalliferous Deposits.

By J. G. Goodchild, F.G.S., H.M. Geological Survey.

(*Read Friday, December 7th, 1888.*)

It is next to impossible to formulate any scheme of classification applicable to metalliferous deposits that is not more or less unsatisfactory in one respect or another. The classification that appears least open to objection is that based chiefly upon the geological relations of the substances under notice. This, at all events, admits of the various facts being arranged in a form more convenient for consideration than do most of the others that have yet been propounded.

In accordance with this scheme, metalliferous deposits are here classified under three primary categories, which are as follows:—

(A) Ores originating as such contemporaneously with the formation of the rocks enclosing them;

(B) Ores introduced into their present position at a later date than that of the containing rocks; and

(C) Ores of detrital origin.

It is obvious that cases must often arise where it is not possible to determine with certainty to which of the three categories any given deposit should be referred, because no hard and fast lines exist; and, moreover, the ores of nearly every metal here noticed can be shown to occur in every one of the three leading modes referred to.

Each larger group includes several important subdivisions. The more prominent of these may be briefly noticed at once.

Under (A) or Indigenous deposits, we find:—

(1) Ores native to rocks of eruptive origin;

(2) Those deposited contemporaneously with associated rocks of sedimentary origin;

(3) The alteration products of either of these.

Under (B) Introduced ores, are:—

(4) True vein-deposits, which graduate into:—

(5) Impregnations, stockwerks, and other forms of ore-deposits introduced into the body of the rock from extraneous sources;

(6) Segregation-products, which represent local concentrations of metalliferous substances originally diffused throughout the enclosing rocks ;

(7) Infiltration-products, which have attained their present position and character after downward percolation from a different and higher group of rocks.

(8) Replacement forms of any of the above.

To these may be added :—

(9) Alteration products arising from

(*a*) The action of forces originating at the surface ; and

(*b*) Those due to causes acting from below.

Under (C) we recognize :—

(10) Detrital ores remaining unaltered ;

(11) Ores, originally of derivative origin, which have since undergone more or less change.

We may now consider these several forms in more detail, commencing with the Plutonic group, A1.

An examination of any large series of rocks of eruptive origin reveals the fact that, besides their normal constituents, the crystalline silicates, they include, amongst other substances, various ores of the metals. Some of these may be safely referred to the reaction consequent upon the changes the rock constituents themselves may have undergone. Some may even be due to introduction from without. But there are others, occurring interstitially amongst the crystalline components of the rock, that appear to represent metallic substances that existed in some form or other in the magma, and that separated at, or about, the period of final consolidation of the rocks themselves. Magnetite, Ilmenite, Pyrite, and other ores of iron are well-known in this relation. Molybdenite certainly occurs interstitially amongst the crystalline constituents of the granite of Shap ; and it is said to occur also under similar conditions in the syenite of Mount Sorrel. Its occurrence in this manner will probably be found to be much more general than has hitherto been supposed. Mr. Bauerman's specimen of Blende from Isåsen, near Askersund, in Sweden, and now in the Horseshoe Case at the

Jermyn Street Museum, forms part of a crystalline mixture with green felspar. Gold occasionally appears in the same relation. Galena occurs in the same way in several localities, notably in Sweden. One of the best illustrations of this kind was presented by the mass of granite from Harney Peak Tin Mines, Dakotah, which was exhibited at the London meeting of the Geological Congress. In this granite Cassiterite occurs interstitially, and with every appearance of being an original constituent of the rock, dating from the period of final consolidation of the plutonic rock enclosing it.

Each one of the minerals above mentioned commonly has other modes of occurrence. But the fact that they do very generally occur in this relation to the matrix enclosing them, or in combination with the constituent minerals forming eruptive rocks, is a point of considerable interest and importance. As a rule, ore-deposits of this kind appear to have originated under conditions of great pressure—probably indicative of formation at a great depth below what was then the surface at that particular point. Perhaps the term *Plutonic* might be as legitimately applied to such forms of ore deposits as to the rocks wherein they are enclosed. We should probably not be far wrong if we regard this plutonic mode of occurrence as the principal starting point in the great series of modifications that remain for us to consider. The metalliferous emanations associated with volcanic phenomena are, really, little else than forms of plutonic deposits modified by a difference of conditions.

(2) Contemporaneous ore-deposits native to rocks of sedimentary origin are chiefly represented by a few deposits of iron-ore, which occur in formations of nearly every geological period. Most of these have, however, undergone more or less alteration, and therefore do not properly fall to be noticed here. One deposit of this nature has lately been described by Dr. C. Le Neve Foster in a paper read in 1886 before the British Association.* The same subject has been more recently described by Mr. Halse ('Trans. N. of Eng. Inst. Mining Engineers,' xxxvi, pp. 103-117). This is the interesting deposit of impure Diallogite and Rhodonite, which occurs as true beds or seams in the Cambrian rocks of Merionethshire. Similar deposits occur in beds regarded as

* 'Manganese Mining in Merionethshire.' See also 'Geol. Mag.,' 1887, p. 38.

of the same age in Belgium. In studying these deposits one is forcibly reminded of the widely-diffused deposits of manganiferous nodules known to occur on the floor of large oceanic areas. In the present case, however, we have to bear in mind the possibility of these Cambrian deposits having been derived in the first instance from the comminuted detritus of still older deposits, which, as the last of the long series of changes that have affected these ancient and highly-metamorphosed rocks, have passed into their present condition of the impure carbonate, and silicate, of manganese.

(3) The alteration-products coming under these two last heads are too complex to admit of suitable treatment here. But one cannot leave the subject without some reference to the strikingly-abrupt replacement of the unweathered carbonate of manganese above referred to by the black oxide. This phenomenon has been well figured by Mr. Halse; and it was illustrated by actual specimens from Merionethshire when the present paper was read before the Association.

(B) The ores introduced into their present position at a later date than that of the rocks enclosing them include some of the most important and interesting of them all. These embrace:—

(4) True vein-deposits. In the face of the prodigious accumulation of literature bearing upon this division of the subject he would be a bold man indeed who would venture to come before the public with any ideas supposed to be new. As a matter of fact, I believe it to be hardly possible. I shall, therefore, only attempt to give some generalizations based upon a pretty large array of facts that have come under my notice in various mining districts during the last twenty years or so; and shall mainly confine those generalizations to such as may be gathered from a study of deposits of lead-ore, as these are fairly typical of mineral veins in general.

Let us first glance at the principal theories that have been advanced to account for the facts observed in connection with metalliferous veins. These may be summarized as follows:—

(1) That they are plutonic in origin, and therefore of much the same nature as dykes.

(2) That they are due to deposition from metalliferous solutions acted upon by electric currents.

(3) That they have arisen through the deposition in a concentrated form of the metalliferous matters detectable by analysis in sea water.

(4) That they are due to sublimation from below, and are, therefore, analogous to the metalliferous deposits that are left in the flues of smelting furnaces.

(5) That they represent so much material that was at one time diffused throughout the rocks adjoining the veins, which has since been locally concentrated.

(6) That they are due to deposition from thermal springs ascending, from deep-seated sources, through pre-existing fissures; the metals, etc., being each left at the points where the ascending solutions met the relief of pressure or the lowering of temperature that resulted in deposition.

There are other theories as well; but we need not notice them here; and in regard to those above mentioned I may at once state that I believe that every one of them has, in one part or another, had a share in the formation of the phenomena under notice. The mistakes that have been made have generally arisen through too exclusive an advocacy of any one of these, without any regard to the rest. Perhaps, if we consider the facts first, we may be in a better position to judge what share each of these agents has taken in the genesis of metalliferous veins.

In many respects the lead-mining districts of the North of England, and especially those parts where the rocks are of Lower Carboniferous age, may be regarded as presenting the simplest and the most easily examined types of mineral veins. In these mining districts there are usually fine sections at frequent intervals, and there are in addition large areas where perfectly bare rock is exposed for considerable distances. The strata are very little altered, and they have undergone so little disturbance, that over considerable tracts of country they yet remain nearly horizontal. Most of the individual beds of rock are exceptionally persistent both in thickness and in mineral character. They consist of alternations of marine limestones (in proportions that vary with the locality examined) with siliceous beds ("cherts"), and with shales and sandstones. The limestones are most constant, but the rate of change of the other components is so gradual that there is in general no

difficulty in correlating even the individual beds with their equivalents many miles away.

All the harder beds are well jointed, and there is evidence of a gradual passage from the simple joint into faults. The mineral veins either coincide with faults or else occur in such a way as to show that they are intimately connected with these dislocations. But it by no means follows that every fault is necessarily a mineral vein. Where the two coincide they are here referred to as fault-veins.

In regard to the faults, it is not difficult to make out four or five well-marked sets, whose magnitudes range from mere cracks with hardly any relative displacement of their sides, up to faults whose throws amount to as much as a thousand feet or more. In each case, as faults, the inference, drawn from a study of a large number of cases, is that their initiation dates from periods long anterior to that of the rocks they dislocate at the present surface; and that, during the varied disturbances that have at different times affected these areas, the rocks have been repeatedly moved, or fractured anew, over older lines of dislocation pre-existing in the rocks beneath. Some of the faults in the Carboniferous rocks are traceable by their effects to distances amounting in some instances to several miles. The details of these effects need not be given here; there are the usual phenomena of dislocation, evidenced by the vertical contact of unrelated strata, by the presence of fault-breccias, and by the frequent occurrence of slickensides. Many of the faults can be traced by their outcrops through a vertical extent of a thousand feet or more; and in no case has any normal fault been found to die out as it is traced downward. Reversed faults may do so; but with these, for the present, we are not concerned.

In regard to the horizontal extension of fault-veins, it may be stated that in many instances one can follow their outcrop along a particular bed of rock, a limestone, for example, through a succession of exposures extending to a distance of several miles. Notwithstanding the uniformity of the rocks traversed by the veins, the contents of the fault-veins commonly do vary, and may even vary considerably, in the distance of a mile or so; and that, too, without reference to any local circumstances that one can discover. At one end the vein-

stuff may include more or less quartz, fluor, and copper-pyrites; and much of the calcareous matter originally present may have undergone molecular replacement by silica. At another point fluor may occur without the limestones showing any evidence of the introduction of silica. At a third locality baryte may form the predominant vein-stuff. At a fourth there may be little else than calcite. Or, in other cases, there may be mixtures of any or of all of these, in proportions that may vary to any extent. In other words, the same fault, traversing the same rocks, has different mineral contents in different parts of its horizontal extent. The same fact comes out in tracing the fault through its vertical extension; only that, in this case, the variation in the character of the mineral contents appears to be reducible to certain laws. Very generally the cheeks or walls of the fault enclose crystalline minerals in deposits of varying extent. These usually occur as masses interstitial amongst the fault-breccias; but they generally show a marked tendency to arrange themselves in sheets parallel to the cheeks of the vein. The commonest minerals are Calcite and Baryte; but Fluor, Quartz, and Pyrite occur in certain localities. It is, however, still evident that there is no constant relation between the prevailing lithological character of the rocks adjoining the veins and the association of minerals occurring therein. For instance, large areas of bedded opaline siliceous strata occur (the siliceous analogues of the limestone beds), and yet a quartz vein in them is almost unknown. It is so, too, where veins traverse large areas of arenaceous rocks, such as grits and sandstones. On the other hand, Baryte is common in nearly all the faults traversing every kind of rock of Newer Palæozoic age. This want of connection between the contents of fault-veins and the lithological nature of the rocks adjoining is a phenomenon of much wider occurrence than seems to be supposed. I would go so far as to state that it is the rule, nearly everywhere. In both their horizontal and their vertical extent the quantity of vein-stuff varies greatly: partly in conformity with the nature of the rocks traversed, and partly as a result of the complex history of the dislocation itself. As a rule, where a vein traverses soft rocks, the quantity of either detrital or crystalline material included between its cheeks is small. The hade of the fault is also subject to considerable variation. The plane of dislocation

tends to follow the main downward direction of the joints where it traverses the harder beds; while amongst rocks that yield most readily to forces exerted laterally, the angle of hade is apt to be low. Fault-veins do not commonly maintain a uniform direction for any great distance. It is quite as uncommon for their course anywhere to follow true curves. One has to remember that the faults are of later date than the joints in the rock; and that during the formation of a new dislocation the rocks yield more readily along a pre-existing zone of weakness than along any other. Consequently, while the predominant directions of the fracture are determined by the main directions of strain or of thrust, or by the direction of old fractures in the rocks beneath, yet the nascent fault constantly tends to follow the direction of first one set of joints and then another, following those joints farthest whose direction most nearly approximate to that of the fracture itself. The trace of a fault, therefore, whether viewed in plan or in section, usually presents a number of both salient and retiring angles. These, of course, tend to be modified more or less under the powerful grinding and crushing resulting from any subsequent movements.

Very commonly a new plane of fracture has been developed in a direction oblique to that of some pre-existing fault. In that case, as in the case of the joints just referred to, the newer plane of dislocation tends for variable distances to merge into, and to coincide with, the older fracture. In this case the prolongation of the newer fault where it parts from the older usually presents many phenomena of interest connected with this interference. Ore is frequently met with in greater quantity at the junction. Very commonly, also, the number of faults on one side of the line of interference is different from what it is on the other. This is readily enough explained in the theory that the interfering fault is the older of the set, and not the newer. Such phenomena of interference are usually known as "*trailing*," the older fault being said to "trail" the faults with whose direction it interferes. The *heaves*, so often described and figured by De la Beche and others, are phenomena of a different nature, and seem to be really due to the faulting of a pre-existing fault. Small dislocations of this nature must also affect the traces of faults (when seen in plan), but they must not be confounded with the trailing just referred to. Very few true north-and-south fault-

veins are known in Britain. Why this is so it is not easy to say. Possibly it may be that the axes of subsidence and of upheaval, which (according to the present writer) have determined the main directions of jointing in sedimentary rocks, do not happen here to have ever run due north and south; and the direction of faults, and, therefore, of mineral veins, have been affected in consequence.

The absence of any clear relation between the nature of the rock traversed and the non-metalliferous contents of the veins has been already commented upon as proof that, whatever may be the case in this respect in other areas, there is not any necessary connection between the two sets of phenomena. Even where the rock adjoining the veins is impregnated with mineral matter of the same nature as that concentrated in the vein it is more than likely that those impregnations have found their way into the rock from the vein, and not into the vein from the rock, as many suppose to have been the case. Be it as it may, it is clear that what is true of the non-metalliferous contents of the veins applies equally well to the ores of the class under notice. There are large tracts of faulted Carboniferous rocks that contain not a trace of any ore except the nearly ubiquitous ores of iron Yet, in some of the tracts adjoining, consisting of the self-same rocks, traversed even by some of the same faults, not only the fault-veins, but every little cavity, or every chink, connected with the fault, may be the repository of ore in more or less abundance. What can be the reason of this difference of behaviour in the two cases?

Let us examine another fact or two that promises to throw some light upon this point. In one part of the district we have been studying it has long been known that the richest parts of the veins are confined, say, to the zones where the veins traverse particular beds of rock. Above those beds, or below, the local miners do not expect to meet with ore in paying quantities. That seems a good fact to get hold of. There would seem here to be some real connection between the richness of a lode and the original constitution of the particular beds of rocks referred to. But appearances are delusive. One may trace the same fault into an adjoining district, still consisting of the very same rock, and then find that the beds elsewhere so productive, here yield little or nothing; and that other beds, say other lime-

stones, are the chief repositories of ore in this locality. This may hold good of all the veins, even though the nature of the rocks, and local circumstances generally, may otherwise not differ in the least. And it is not alone to limestones that these observations apply. In one part the occurrence of rich deposits of ore may be restricted to the part of the veins that traverse the peculiar siliceous beds lately described by Dr. Hinde.* In another area, still consisting of the same association of rocks, neither the limestones nor the cherty beds just referred to yield any ore worth mentioning, all the rich deposits in this case occurring exclusively in the sandstones and grits. (It may be mentioned here that shales and clays, and soft strata generally, do not commonly afford ore, except where the cheeks of the fault happen to enclose much fault-breccia.)

It requires but a brief consideration of these well-known facts to convince one that, whatever may be the true cause of the filling of metalliferous veins, segregation from the rocks adjoining can, at the best, have played but an unimportant part. Were that the true explanation, we ought to find a much more general distribution of ore throughout every district where suitable conditions prevail, and we ought to find ore in every joint or other divisional plane, or in every cavity, that may occur within these rocks. This has been shown to be very far from being the case.

There is another set of facts to be taken into consideration in connection with the vertical extension of ore-deposits. This, as is well-known, varies much with the nature of the rocks traversed, as well as with the nature of the particular mineral that may be under consideration. But confining our attention for the present to the lead veins traversing the Carboniferous rocks of the North of England we find that in the majority of cases where both an upper and a lower limit of occurrence have been proved that these enclose a zone that rarely exceeds a few hundred feet in vertical extent. A series of veins is most productive of lead-ore at, say, an horizon about a thousand feet above the sea-level. Ore, in gradually decreasing quantities, occurs up to an elevation of, say, twelve hundred feet, and downward to eight hundred feet above the sea-level. Above and below

* 'Geol. Mag.,' 1887, 435. See also J. G. Goodchild, 'Trans. Cumberland and Westmoreland Association.'

these levels ore ceases to be found, although, to all appearance, the local conditions may appear to be eminently favourable. Ores of other kinds than those of lead may, and often do, occur in these positions; but with these, for the present, we are not directly concerned. Now, if we compare a series of facts of this nature, gathered from a large area, a very interesting point can usually be made out. We find that, regarded in a broad and general way, there are certain points where the occurrence of ore in any given set of veins reaches a maximum elevation above the sea, while around those points the upper limit of occurrence of the ore in the several veins falls successively to lower and lower levels in proportion to their distance from those highest points. This feature could be made clearer if we had before us a kind of skeleton-model of a metalliferous district, constructed so as to show at a glance the relative position of all the ore-bearing portions of all the known veins. We should then see that an imaginary surface connecting all the upper, or all the lower, limits of occurrence, would take a convex form, and that the upper and the lower surfaces would together enclose a space whose form one may liken to that of an inverted saucer, or to a meniscus with the convex side upward. It is not, of course, implied that the curves exhibit anything approaching regularity; they are known to be, on the contrary, very irregular, but the figure may serve to convey a general idea of what is meant.

Given a series of meniscoids of this kind, it is not difficult to understand how, in a district intersected by deep valleys, the general relief of the surface might be in one part above and at another part below the level of the metalliferous portion of the veins. In some cases the very highest ground may be below the original zone of deposition, while in another part the bottoms of the valleys may lie above the upper surface of the meniscoid.

There is in some localities a very curious relation between the larger flexures of the rocks and the presence or the absence of ore in the veins. This fact was much insisted upon by Mr. Wallace in his well-known book on the 'Laws which govern the Deposition of Lead-Ore.' Further reference to this will be found below.

Another relation equally curious and equally instructive can occasionally be made out between the distribution of the richer

deposits of lead-ore and the present form of the surface. I was much struck with this fact many years ago, and it occurred to me then that the deposition of the ore might be of later date than the initiation of the present valleys; but the idea was scouted at the time. Mr. Geikie's study of the behaviour of some of the Tertiary basic dykes,* however, shows that the same phenomenon may be observed in both. In the cases referred to, the upper limit of the ore in the veins is rudely parallel to the present configuration of the surface; rising within the hills, and falling along the depressions. The depressions referred to have long been known to be simply the modified descendants of water-courses whose initiation took place at a level higher than the bottom of the present valleys in some cases by two thousand or more feet. Probably the filling of the veins in this case dates from one of the earlier stages in the formation of the present valley; and the parallelism between the deep-seated phenomena and the surface features points to former variation in the downward increment of temperature connected with the shape of the ground when the veins were formed.

As bearing upon the age of the North of England lead-veins, one or two other points remain to be considered. The faults wherein the veins occur probably date back in many cases to very remote geological periods. As zones of disturbance and of dislocation, many of them certainly may be referred to periods long anterior to the date of the rocks they now affect at the surface. There is plenty of evidence to show that, as zones of weakness, they have acted as faults again and again at various periods since. The fault-breccias are scrunched and slickensided in a manner that points to the repeated exertion of powerful mechanical forces in times past. In remarkable contrast to this evidence of powerful grinding and crushing is that afforded by the crystalline contents of the veins. There may be, in a few instances, some kind of evidence of these vein-minerals having been disturbed since they were formed; but as a rule the evidence tends to show that since the date of formation of these minerals there has been no vertical displacement of the opposite cheeks of the fault. Large masses of crystals occur without the slightest sign of any break during their growth from first to

* "The History of Volcanic Action during the Tertiary Period in the British Isles," 'Trans. Royal Soc. Edin.,' xxxv, pt. 2, pp. 54, 55.

last, and the crystalline faces of many of the minerals, such as Fluor, Baryte, Galena, and others, are just as perfect as when the minerals were first formed. The significance of this very common feature of mineral-veins does not seem to have been generally perceived.

Another equally well-known feature in connection with mineral-veins calls for remark here. This is the "comby" structure of lodes, and the evidence of the deposition of vein minerals in successive layers. This clearly points to the fact that during the filling of the vein there were occasional interruptions of deposition, which were contemporaneous with more or less lateral disruption of the veins and their contents. After the formation of the earliest stages of the comby structure there has been no displacement along the plane of the fault.

Such a condition of things, extending over a large area, can only have obtained under conditions of upheaval. This seems to indicate that the introduction of the lead-ores of the North of England took place at, or about the close of, the last period of upheaval. This, by independent reasoning, I have inferred to be contemporaneous with the last manifestations of volcanic energy in Tertiary times;* and all the evidence yet brought forward seems uniformly to support that conclusion.

In regard to minor details connected with the mode of occurrence of these lead-ores, not much need be added. The hade of the vein seems to exercise some influence upon the richness—perhaps only because a low hade is often due to the vein traversing shales, which rarely or almost never yield ore. Direction does seem in a few cases to exercise a certain amount of influence upon the richness of the metalliferous contents of the veins; a possible reason for which will be referred to below. In certain areas, often restricted in a very curious manner, the parts of the rock adjoining the metalliferous zones of the veins, where that rock happens to be limestone (but not commonly in other cases), are more or less impregnated with ore. The usual mode of occurrence is that of an irregular extension of ore-bearing ground from the vein along the divisional planes of the rock, most frequently along the

* See upon this the writer's 'History of the River Eden," *Carlisle Journal*, &c., 1880; and "The Physical History of Greystoke Park and the Valley of the Petteril," 'Trans. Cumberland and Westmoreland Association,' xiii, p. 69.

planes of bedding. These the mining folk call "Flots," a good old Teutonic word, which has been most unfortunately "corrected" into "flats." These flots play a very important part in the commercial value of the lodes in certain districts, while in other districts the phenomenon is quite unknown. The distinctions made between rake veins (the word "rake" being an old north-country word, conveying the idea of any kind of linear extension) and pipe veins, seems to me to be one of very little importance in the present connection. In every case yet made known the pipe veins appear to be connected with faults: that is to say, they communicate with the interior of the earth, and are not of the same character as swallow-holes and the like, as their name would suggest. On the other hand, true pipes, *i.e.*, funnel-shaped cavities terminating a short distance downward, represent a very common mode of occurrence of hæmatite.

In the case of the lead veins traversing rocks other than Carboniferous, *e.g.*, those in the older palæozoic strata, some few differences of minor importance can be made out. Most of these old veins contain quartz as their chief vein-mineral, which braces the cheeks of the vein together into firmer contact than is the case where more friable minerals fill the cavity. In other respects the larger features are much the same in both cases.

In regard to the origin of these vein-deposits of lead-ore, it is hardly possible to state anything that is new. The balance of evidence appears to me to be decidedly in favour of the view that, in the great majority of cases, the lead-ore has been mainly, or entirely, introduced into its present position, in its present state, by the agency of thermal springs rising through pre-existing channels, under conditions of great pressure. One has to bear in mind the fact that the solvent power of water increases with increase of pressure as well as with increase of temperature. Increase the pressure, or raise the temperature, and water alone, without the aid of other solvents, is capable of dissolving almost any substance. Diminish that pressure, or lower that temperature, as the case may be, and the depositing point of one or other of the substances in solution is attained, independently of

chemical reaction from the introduction of other substances, which, of course, may also play an important part.

Now, in a district undergoing elevation, as one of the manifestations of waning volcanic energy, there must always be, deep below the surface, the precise conditions requisite for the formation of mineral veins. Take the case of the North of England. Here, as Dr. Archibald Geikie has lately shown, there is abundant evidence of the exertion of intense volcanic energy in the Tertiary period (possibly in Oligocene times). A very large area appears, then, to have formed a mere shell or crust over a vast subterranean reservoir of molten rock, which, under conditions of great pressure, eat its way upwards, along certain lines of weakness, as far as the local temperature, or the nature of the invaded rock, then permitted, and subsequently consolidated as dykes. There are reasons for believing that many of the larger features of the present surface had, even then, been already outlined: outlined, that is to say, in rocks two or three thousand or more feet above the mean level of the present modified descendant of that ancient land surface, the present horizon above the sea being then, probably, far beneath that level. There seems, also, evey reason for believing that the intrusion of this vast quantity of igneous rock took place during the upheaval of the district, when the whole area was being subjected to lateral tension consequent upon the increased horizontal dimension necessarily assumed by the rocks in passing from part of a smaller sphere to a larger. It would be during the waning of such a set of conditions that thermal waters would be forced upwards from the main centres of Plutonic activity, whence they would penetrate every accessible plane of weakness within the rocks around. Abundant channels of communication between the exterior and the interior already existed in the shape of faults. Along these, therefore, the thermal waters were forcibly injected, and during the earlier phases of the more violent paroxysms of upheaval, such waters would be, necessarily, subjected to great pressure, which pressure, like the temperature, would augment with increase of depth. Now, any metals taken up in solution near their parent sources in the plutonic masses would be carried upward by the thermal waters as far as the point where the solvent power of the water had passed their

respective depositing points. This position would vary extremely in the case of different mineral substances, but differences of pressure, of initial temperature, and of the thermal conductivity of the rocks adjoining, must also have influenced the position of the depositing zone. Variation in temperature, due to the downward circulation of cooler surface waters, or the proximity of synclinal axes, or any cause that deflected the isogeotherms, must also have influenced the results in various complex ways.

Take the case of any fault through which an ascending current maintains a uniform temperature at a given horizon for some time. Here, all the while the pressure remains uniform, the depositing point of some mineral substance would remain constant also. But with a slight change of conditions the pressure augments, the solvent power of the water at that point is increased, dissolution of the minerals commences, and they are transferred in their new state to a higher level. Then follows upheaval, with consequent dilation of the cheeks of the vein, and relief of pressure. With the change of conditions the depositing point again shifts to a lower level. In this way successive layers of vein-stuff are formed, and comby structure and other complexities result. We have to bear in mind also the important fact that, in many cases, the position of deposition for each mineral would differ from that of others; so that, supposing the conditions of pressure, temperature, and of chemical reaction, in any given vein remained for a time constant, there would even then be a definite vertical succession of minerals deposited, those most difficultly soluble being left at lowest points, while some few of the others might be carried in solution far enough upward even to find egress at the surface. But the solvent power of the current traversing any such channels probably never is long maintained with uniformity at any one point. Consequently it must often happen that the zone of deposition of a more soluble mineral will sometimes be nearer the source of the spring, *i.e.*, at a lower level, than that of a less soluble mineral previously deposited. The converse would, of course, ensue with augmentation of solvent power. If the volcanic activity declined gradually (which, beyond a certain point, does not seem to have been generally the case), then the zone of deposi-

tion for each mineral would gradually fall to lower levels, and a continuous deposit of the last found ores would extend from the highest zone down to an indefinite depth. Although this does not by any means seem to have been generally the case, it will enable us to understand how deposits of the minerals characteristic of the higher zones may occur in direct association with those pertaining to deeper levels. We have an exact parallel to such cases, where trappean, or volcanic, rocks invade a prior-formed mass of rocks of plutonic origin.

On this view of the mode of formation of the chief mineral veins there should be no difficulty in accounting for the phenomena connected with stockwerks, impregnations, and the like. Under the conditions of maximum pressure and temperature such as must have prevailed near the sources of the thermal springs, the metalliferous solutions must have permeated the rocks, often to a considerable distance on each side of the fissures and planes of weakness connected with the faults; and the solvent power exerted, under such conditions, upon certain of the rock-constituents themselves, must have constituted an important factor in diffusing the ores through the substance of the rock. Such conditions might be expected to obtain in contiguity to any nascent mass of eruptive rock, and might prevail equally both above that mass and below it. Some very important observations upon the stockwerks and other forms of impregnations in the rocks of the Cornish mining districts have been published by Dr. C. Le Neve Foster in the 'Quarterly Journal of the Geological Society' and elsewhere.

(6) Segregation products.—These are well exemplified by Pyrite, Clay Carbonate of Iron, and a few others. A few small deposits of Galena, Blende, Chalcopyrite, Millerite, and some other mineral species have certainly originated in this way, and are not of uncommon occurrence in the interior of nodules of clay-ironstone, or even within fossils. It is far from unlikely that a few exceptional deposits of a more important character may with propriety be classed under the same head. Metals in various combinations are known by analysis to exist in small quantities diffused throughout derivative rocks of many kinds; and it is more than likely that, under certain conditions, some of these ores may readily travel in solution

through the body of the rock and eventually become concentrated at particular points, and thus assume proportions of economic importance. Certain impregnations may really be of this nature, although I am inclined to regard the majority of them as having been introduced into the body of the rock from the fault-veins, and not into these from the rock.

In regard to the original sources of the materials that have thus segregated from a state of diffusion, we should probably not err greatly in referring the majority to igneous rocks of some kind or other, as these can be shown in many cases to be the vehicles wherein the ores of the metals have been transferred from lower to higher positions in the earth's crust. They seem to have been first carried up in these rocks, and then to have been in part dissolved out, and subsequently redeposited at lower levels. But much of the ore existing in a diffused state in rocks of derivative origin has been derived directly from the waste of old land-surfaces. Ore-deposits must have been formed at nearly all periods of the earth's history, and they must have undergone disintegration and waste as much in past times as at the present day. Hence, we need feel no surprise at meeting with traces of the degraded material in old sedimentary deposits, any more than we should in meeting with such in the modern alluvium in the lower parts of any metalliferous district. Detrital ores of this kind might even remain in nearly their original chemical condition, provided that the nature of their surroundings favoured their preservation.

(7) The metalliferous deposits that have originated by downward infiltration from some higher rock have already been incidentally alluded to in connection with igneous rocks as vehicles of ore-deposits. But in certain other cases it is easy to conceive that rocks of sedimentary origin may play much the same part, and may represent the source whence important deposits have originated. Red rocks of all ages, but especially the New Red rocks, for example, have acted as the repositories of many valuable deposits of iron-ore. The precise mode of introduction of the iron into these rocks does not concern us at present: it exists there still, and in large quantities. It is also equally certain that in earlier times the store was even more extensive, but that it has been diminished by long-continued

draining of the iron to lower levels into the rock beneath. Vast quantities of this ferruginous matter have soaked down from the New Red into the Carboniferous sandstones, for example, staining these, in many cases, of almost as bright a red as the sandstones of the New Red itself. In other cases where the rocks are less permeable, some of the irony matter has been arrested, and has been concentrated in continuous masses. Where limestone, or veins of calcite, or indeed calcareous matter of any kind, has been acted upon by these downward percolating ferriferous solutions, some very interesting chemical changes have ensued. It is not uncommon to find a fossil, an encrinite stem, for example, that has been exposed to such conditions, partly changed by molecular replacement into iron-ore. There are several good examples of this in nearly every mineral collection, notably at the Museum of Practical Geology. One end of the stem of the encrinite may remain nearly in its normal condition of carbonate of lime, the middle of it may be more or less dolomitized, and the opposite part be found to graduate into pure hæmatite at the end; the original features of the fossil remaining otherwise unaltered. What happens in a small specimen may be traced equally well on a much more extensive scale in the field. Great masses of calcareous rocks have been irregularly replaced, in some cases entirely replaced, by hæmatite; the non-calcareous matter associated therewith remaining unaffected. Thus where chert-nodules occur in a limestone under those conditions the chert-nodules remain simply as chert, while the limestone that originally enclosed them has been bodily replaced by hæmatite. So where beds of shale happen to extend through a limestone series, the shale is merely altered in colour; but the associated limestone has passed into beds of iron-ore. It was Mr. J. D. Kendall who first called attention to the true significance of this fact, and who pointed out its bearing upon the origin of hæmatite.* My own observations had independently led me to much the same conclusion. But Mr. Kendall's wide knowledge of the facts enabled him to prove beyond dispute that our British deposits of hæmatite, and, inferentially, many others also, are simply substitutional, or pseudomorphic in character.

From Mr. Kendall I differ in referring the date of formation

* 'Trans. N. of England Inst. Min. Engineers,' Vol. xxviii, p. 107.

of the hæmatite to one later than that of the New Red, as I regard the so-called pebbles of hæmatite that occur in so many of the New Red breccias and conglomerates, notably those of Somerset and of North-West England, simply as pebbles originally of calcareous matter, which has been subsequently converted into hæmatite by precisely the same means as those that have converted the Carboniferous encrinite stem above referred to into iron-ore.* As pebbles of limestone, these are, of course, contemporaneous with the New Red; while as pebbles of hæmatite, there is no reason why they should not be of Tertiary age, or even be in process of formation now.

It is very remarkable in most of these cases of replacement of calcareous matter by hæmatite, that no trace of carbonate of iron as an intermediate stage should exist. There is nearly always Dolomite, but I have never seen Chalybite in this relation. Nodules of clay-ironstone are, it is true, often converted wholly, or in part, into hæmatite under the conditions mentioned. Those of the Argill Coal-Field near Appleby, afford good illustration in point, and others, better known, are presented by the iron-ores of Froghall, in Staffordshire, where these replacement-products were at one time worked for iron-ore.

Manganese in several mineral forms is of common occurrence in association with hæmatite, under the circumstances just described, and it may occur separately. Like hæmatite, it occurs in a very irregular, pocketty, sporadic kind of way, as one might expect of any deposit originating in the way above described. The evidence of replacement in the case of these ores is not, however, always as clear as it is in the case of hæmatite.

Hæmatite, of course, occurs in a great variety of ways—in volcanoes, from the reaction of steam upon chlorides of iron arising from sublimation; in lodes, from other causes, and so on, under sufficient variety of circumstances to illustrate the observations made at the commencement of this paper.

(8) The alteration-products of this group do not call for any particular remark. Everywhere change is proceeding, though at varied rates in different cases; and most of the changes can

* See J. G. Goodchild, 'Trans. Cumberland and Westmoreland Association,' No. vii, p. 116, *et seq.*, and p. 169.

be traced to the direct action of meteoric causes. Some of the older deposits of hæmatite, for example, have suffered disturbance and disruption to the same extent as their parent rocks, the New Red. In the north of England, as elsewhere, vast areas of New Red rocks have been upheaved to considerable elevations above the sea, and, in course of time, as the New Red rocks themselves have there wasted away before the action of subaerial forces, the platforms of older rocks have been re-exposed, and with these are re-exposed also some of the deposits of hæmatite. Part of the Lake District *massif* may be shaped out of an old plain representing the re-exposed floor of the New Red, as also may be the general surface of the great Carboniferous uplands lying to the east of the Pennine faults.* In these cases part of the hæmatite so exposed has undergone many changes. Some of it has been converted into manganiferous limonite. Some of it, being carried down as ferriferous solutions, has encountered solutions of some of the alkaline carbonates on the way, and in consequence has been converted into siderite. This mineral occasionally replaces certain beds of limestone. Other parts of the original hæmatite have been converted into ochre, or have been otherwise changed more or less from their original condition. All of it seems to have been hæmatite originally, and all to have been derived from the New Red, before this was dislocated by the later movements of the Pennine faults.

(9) The alteration-products arising from causes affecting the contents of mineral veins may be arranged under two heads:—

(*a*) Those due to causes acting from above downwards, most of which originate at the surface.

(*b*) Those arising from chemical or other reactions proceeding from below.

We may best consider some of the more important of these by studying such veins as those of the Caldbeck Fell area, in Cumberland, which are as well known to students of British mineralogy as any locality in the kingdom. These veins are probably of very high antiquity, and have served, time after time, as the channels of communication between the foci of plutonic action and the outer portions of that part of the earth's surface. As a consequence, the earlier suite of the vein-

* *Ibid.* viii, p. 199; ix, p. 31.

minerals embraces a wide range of species, not counting those of later introduction, or those due to subsequent change. The date of introduction of the ores of lead, copper, iron, and manganese is almost certainly posterior to that of the plutonic minerals with which they are at present associated, and the date of upheaval of the general *massif* that encloses the veins is later still. The old quartz veins, charged with Apatite, Wolfram, Molybdenite, Mispickel, &c., and various complex silicates, became the repository, in Tertiary times, of Galena, Chalcopyrite, Blende, and some other minerals. It is more than probable that the New Red, and even part of the Cretaceous rocks, may have covered this area at the time, and that the rocks now forming the surface, and with them the zones of metalliferous deposition, were then at a lower level, perhaps by thousands of feet, than they are at present. With the waning of the great Tertiary volcanic outbreak, and the intrusion of thermal waters during the exertion of the forces that eventually gave rise to intermittent upheavals, the later metalliferous deposits were left near the sources of the hot springs. Then, as the newer rocks were stripped off by denudation, and the higher and non-metalliferous parts of the veins were consequently removed, the ore-bearing zones became, by degrees, exposed to the action of surface-waters and other agencies operating downward from the surface.

Part of the contents underwent mechanical disintegration along with the general rock-surface, and fragmentary ores were carried seawards, here and there becoming interbedded with fluviatile or with lacustrine alluvium. Other portions underwent much more complex changes of a chemical nature, whereby they constantly tended to enter into fresh combinations and to be left, for a time, at lower levels, thence descending to lower levels still, and continuing to enter into combinations of increasing complexity, as the general level of the surface was lowered. Galena decomposed into Cerussite, often remaining for a time (as there is little or no calcareous matter here) in the preliminary condition of Anglesite. The decomposition of the compounds of Tungsten, of Apatite, Mispickel, Pyrite, etc., dating from the older or plutonic set of vein-deposits, liberated substances that recombined with the decomposition-products resulting from the oxidation, etc., of the ores of lead, copper, iron,

and zinc, at higher levels. Added to these were the minerals that worked their way downward along the vein-channels from such deposits as the New Red. It is doubtless to this source that is to be attributed the deposition of the complex ores of iron and of manganese that occur along with the true vein-minerals there. Both of these metals seem to have replaced calcite, or calcareous matter of any kind already existing in the veins. Fluor does not seem ever to have entered very largely into the contents of these veins; had it been otherwise the number of mineral species found in these veins would probably have been greater even than it is. Nor do the hot springs seem to have carried up Cinnabar or Mercury in any form; otherwise some of the gold liberated on the decomposition of the Pyrite might have been concentrated in nuggets or other forms.

The history of the decomposition-products just referred to will serve to exemplify this portion of the great cycle of changes that all such deposits undergo. In most of the North of England veins, however, the results have not been, as a rule, by any means so complex as those above noticed. The Cornish mines, or those of Leadhills, present us with the nearest parallels. In any case it is important to realize that the vertical succession of minerals in any given vein represents the net result of all the complex changes and reactions that have affected that particular channel from its initiation down to the present day.

C. (10) Detrital deposits hardly call for any special remark. They occur in a variety of forms, whereof the two most important are (*a*) those associated with ordinary sedimentary deposits; and (*b*) those due to detachment, by various causes, from the cheeks of the lodes where they were left originally. Stream deposits of all kinds, stream tin, alluvial gold, and the like, exemplify one form of the first; while detrital ores of much higher antiquity are well represented by such deposits as the famous ones of Mechernich,* which are regarded as having been, primarily, derived from the broken-up materials of lodes traversing the Devonian rocks of the districts adjoining. The fact that these Mechernich deposits still remain in nearly their original condition need not surprise us, for, provided the ores are protected from the action of the forces that elsewhere are

* See J. A. Phillips, 'Ore deposits,' p. 266, *et seq.*

constantly tending to bring about change, such alteration may be retarded for an indefinite length of time. As metalliferous deposits of the same kind as these now forming must have been laid down at almost all periods of the earth's history, there does not seem any valid reason why lodes of even Cambrian age may not still be in existence, if these have chanced to be adequately protected from those agents of reconstitution that are unceasingly at work elsewhere. On the other hand, it is almost certain that other deposits of the same minerals, dating, perhaps, no farther back than the last few thousand years, may have long since passed through the whole cycle of changes and have again returned to the plutonic condition.

Brecciated ores are of common occurrence in veins. In many of the cavities connected with the lead veins traversing the limestones of the North of England, for example, such deposits have long been known. Here they present the character of pockets of clay, through which are scattered broken masses of galena and other minerals. Some, at least, of these seem to be due to irregular solution of the roof or the higher parts of a chamber coeval with the lode, the limestone being dissolved away, while its adherent crust of ores has fallen into the mud that nearly always occupies these cavities. Possibly, in a few cases, the masses of galena may have grown by the accretion of plumbiferous solutions derived from the higher parts of the vein itself; these chambers forming, as it were, a kind of eddy during the general ebb of the vein-contents. Other such masses, probably having a similar history, often occur in the vein itself. Sometimes, as might be expected, the brecciated character of the ores is clearly due to differential movements of the cheeks of the lode.

(11) In regard to the changes that detrital ores undergo, incidental references have been made already. Perhaps one of the best illustrations of an extreme case of the kind is presented by the well-known and oft-cited case of the stag's antler, which was discovered in one of the Cornish deposits containing stream tin, and was found to be partly converted into tin-ore. Perhaps in this case some of the stream tin may have entered into combination with fluoric acid, derived from decomposing fluor spar (which is common as a vein-mineral there), and the resulting

stannic oxyfluoride may have been partly reduced by the agency of the decomposing organic matter of the antler. The instance is very instructive as showing that, under suitable conditions, the transmutation of even tin-ore may be going on near the surface at the present day.

Minute quantities of diffused detrital gold may, in like manner, be locally concentrated in the form of nuggets if the auriferous matrix be permeated by heated vapours carrying mercury in a volatile state.

Experimental Geology:

Being an Address delivered at the Annual General Meeting of the Geologists' Association on February 1st, 1889,

By F. W. Rudler, F.G.S., President.

For many years it has been the custom in this Association for the Anniversary Address to be delivered at the opening of each session in November. The Council has, however, recently decided that it would be in many ways more convenient to receive the address at the Annual General Meeting in February; a decision which has at least the merit of bringing our anniversary proceedings into harmony with the practice prevailing in most other societies. By this wholesome innovation it becomes my privilege to solicit your attention for a short time this evening, before resigning the chair. Like the swan which is fabled to sing its song on the eve of death, I find that the closing act of my official existence comes to be the delivery of this address.

In casting about for a subject which would lend itself to that breadth of treatment which, if not absolutely necessary, is unquestionably desirable for presentment in a presidential discourse, I have sought to avoid all topics which have been brought forward by previous occupants of this chair. Almost every aspect of our many-sided science has in turn been presented to the Association; but there has not to my knowledge been any attempt to put forward the claims of *Experimental Geology*. I have hence been induced to select this theme as the basis of some brief observations on this occasion.

Possibly no better definition of "experiment" can be found than

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Possibly no better definition of "experiment" can be found than

that used by Sir John Herschel, when he defined it as "active observation."* The business of a geologist is usually confined to the passive observation of facts and phenomena; and this as a rule is all that he can hope to accomplish. Most departments of geological science are incapable of elucidation by experimental methods; the field of experimentation being limited to the petrogenetic and the dynamic branches of the science. Even "chemical geology," said the late Prof. Jevons in his 'Principles of Science,' "is generally beyond the scope of experiment."† By which, I presume, he meant that the chemical operations involved in geological phenomena were often too complicated and too slow to be successfully imitated by experiment. At the first blush of the subject it may perhaps be said that the geologist becomes an experimentalist whenever he introduces artificial conditions to assist in the observation of nature. If, for instance, he is anxious to ascertain the character of the strata hidden beneath his feet, and to that end sets to work "to drill and bore the solid earth," does he not become in a limited sense an experimentalist?‡

A moment's reflection, however, will show that the geologist who makes a trial boring or undertakes an experimental sinking, is no more entitled to rank as an experimentalist than if by means of his hammer he simply struck a chip from a rock in order to examine the character of its fracture.

* 'A Preliminary Discourse on the study of Natural Philosophy,' by J. F. W. Herschel, 1831, p. 77.

† 'The Principles of Science,' by W. Stanley Jevons, Vol. ii, 1874, p. 48.

‡ This mode of exploration is now practised to a considerable extent by some of the members of the Geological Survey, who are working in areas which contain beds of soft or loose material, such as clays and sands. These experimental borings are made with ease and rapidity by means of the tools employed by the officers of the Geological Survey of Belgium and described a short time ago by MM. Van den Broeck and Rutot ("Un nouvel appareil portatif de sondage pour reconnaissance rapide du terrain," par E. Van den Broeck et A. Rutot, 'Bull. de la Soc. Belge de Géol. de Pal. et d'Hydrologie,' ii, 1888, pp. 135-196). Imported from Belgium, the tools have been used in this country chiefly by Mr. Clement Reid, who has turned them to excellent account in probing the strata in the northern part of the Isle of Wight. And here it is pleasant to recall the fact that the introduction of the Belgian hand-borer into this country was due to the visit of the Geologists' Association to Belgium in 1886, when Mr. Topley, at that time President, realizing the value of such an aid to investigation, lost no time in securing its advantages for his colleagues at home. At our excursion to Wimbledon last April, Mr. Reid demonstrated the use of this apparatus. Nor is it only by the Survey that experimental borings have been recently undertaken for geological research; similar means having been employed by Mr. Horace Brown, F.R.S., in studying the Permian rocks near Burton-on-Trent.

In either case he unquestionably sets himself in action for the purpose of discovering something which is not superficially evident; but his activity discloses nothing more than may be elsewhere revealed without human intervention. The case is rather different, however, when in examining a rock he touches it with a drop of acid; for here he introduces, in the cross-examination of nature, conditions which are purely artificial, and he forthwith becomes in a restricted, though genuine sense, an experimentalist.

It is thus obvious that in order to constitute a geological experiment, human interference with nature, though a necessary, is not a sufficient condition. Everyone will readily recall a multitude of cases in which the activity of man has exercised a conspicuous influence in controlling those operations of nature in which the physical geologist is interested; and yet no one would cite these cases as geological experiments. Thus, the destruction of a forest may increase the erosive power of neighbouring streams and enable them to cut out gorges for our instruction; or the embankment of a river may so alter its velocity and transporting power that it is enabled to carry an increased burden of sediment to its estuary, where the deposits may form new land and thus alter the coast-line.*

It is only, however, by a loose employment of language that operations of this kind—interesting as they may be geologically—can be called "geological experiments:" otherwise the civil engineer should rank high in our science as an active experimentalist. In one sense the bold experiment of M. de Lesseps to cut a continent in two may be regarded as a geological experiment of the first magnitude, inasmuch as his scheme, if executed, would undoubtedly be fraught with results of no mean interest to the geologist. It is true that in such cases man does disturb the economy of nature in a way that offers many a useful lesson to the geological observer; yet his efforts are not directed of set purpose to this end, and whatever geological results may follow in the train of his activities, are not only subsidiary but purely accidental.

At the same time, it must be remembered that in a geological experiment the conditions are not necessarily selected by the observer beforehand in order to effect the end which is ultimately

* For much valuable matter bearing upon this subject, see the late Mr. G. P. Marsh's 'Earth as Modified by Human Action,' a new edition of his 'Man and Nature.' London and New York, 1874.

attained. Take, for instance, the earliest observation in experimental geology recorded by the Geological Society of London. In the first volume of the 'Transactions'* is a short note by Mr. Pepys on the formation of iron-pyrites. It appears that this chemist, having occasion to prepare a quantity of hydrogen gas, proceeded, after the manner of his day, to act upon iron-filings with sulphuric acid, and thus obtained as a by-product several quarts of an impure solution of sulphate of iron, which he left in an open pitcher exposed for a twelvemonth in his laboratory. It happened that during this time a number of mice accidentally fell into the liquid, and the decomposition of their tissues reduced the salt to the condition of a sulphide, so that eventually small grains of iron-pyrites were found in the sediment at the bottom of the vessel.

Here the experiment was made by pure accident, yet the result was as valuable as though it had been the outcome of prearranged conditions. Mr. Pepys might have observed that iron-pyrites is often associated in nature with organic matter; he might have found it in fossil wood or in the casts of shells, or impregnating the tissues of bone. This association would naturally suggest the existence of some causal relationship between the organic bodies and the pyrites; and the reducing action of decaying animal and vegetable matter upon a sulphate would immediately suggest itself as a probable mode of origin for the mineral. That a solution of ferrous sulphate should be naturally deoxidized in this way would be in the highest degree probable; still, it would be only a hypothesis until verified by the touchstone of experiment. If Mr. Pepys, after reasoning in this fashion, had of deliberate purpose added organic matter to the solution of green copperas with the view of watching its gradual operation, he would unquestionably have been an experimental geologist. Is he less so because the organic matter was fortuitously introduced?

Much of what is called experimental geology is in truth the observation of artificial processes which have been carried on under known conditions, but yet not directly by the determinate intention of the observer. Thus, in M. Daubrée's classical volume on experimental geology,† several chapters are devoted to the

* "Notice respecting the Decomposition of Sulphate of Iron by Animal Matter," by W. H. Pepys, Esq., F.R.S., 'Trans. Geol. Soc.,' Vol. i, 1811, p. 399.

† 'Etudes Synthétiques de Géologie Expérimentale,' par A. Daubrée. Paris, 1879.

record of observations on the formation of minerals in the masonry around the hot springs of certain Roman baths in France. These observations are worth a brief reference, inasmuch as they are typical of a large class of historical experiments which have resulted from an accidental combination of circumstances originally unforeseen.

Picturesquely seated in one of the valleys of the Vosges is the watering-place of Plombières. The thermal waters of this locality, like most other mineral springs, were well-known to the Romans, who prized their virtues so highly that they established baths on the spot. Around the springs were built walls of concrete, composed of fragments of brick, and either sandstone or limestone, cemented with lime. The temperature of the waters is not high, the warmest springs being below 70° C.; while the proportion of mineral matter carried in solution—chiefly silicate of potash—is so small as not to exceed 30 milligrammes to the litre. Yet this weak solution, constantly circulating through the concrete, has given rise to chemical reactions of a most interesting character, resulting in the formation of such zeolites as chabasite, mesotype, and apophyllite, with other minerals of more common occurrence, like calcite, aragonite, and opaline silica.

Here, then, we have an experiment which was started unwittingly by the Romans, and has been running for well-nigh twenty centuries. The results are consequently such as we could never obtain under our eyes in the brief course of a laboratory experiment. In seeking to imitate Nature we are usually at a disadvantage through lack of time for the accomplishment of the reactions. The geologist can never get his experiments made by a chemical Methuselah. In the hurry of life we are forced to hasten the reactions by employing strong solutions in place of the weak ones with which Nature commonly operates; and it is probable that in this way we often import an element of grave error into our results. We proceed on the ground that a strong solution acting for a short time is equivalent in its effects to a weak solution acting for a long time. But this equation between the methods of Art and of Nature, though in most cases highly probable, is usually assumed rather than proved.

Although the artificial zeolites were first observed at Plombières, similar products were subsequently discovered by M. Daubrée in Roman masonry connected with thermal springs at

Luxeuil (Haute-Sâone), at Bourbonne-les-Bains (Haute-Marne), and near Oran in Algeria. There is, therefore, nothing peculiar in the waters of Plombières to account for the reaction. In fact, only a small proportion of the elements of the artificial minerals has been derived from the waters; the remainder pre-existed in the concrete, and it is possible that even pure water might, under certain conditions, give rise to the production of these zeolites.*

The contemporaneous zeolites in the cavities of the Roman bricks may be fairly compared with those which are well known in amygdaloidal basalts and melaphyres. The tourist who brings from the Giants' Causeway his little geode—its walls studded with sparkling crystals, or its cavity traversed by glassy needles—may read the history of his specimen by the light of these remains. Between the Tertiary basalt and the Roman brick there is a close analogy. Thermal waters rising from deep-seated sources, or even meteoric waters filtering downwards through the igneous rock, must tend to decompose some of the mineral silicates which are present as constituents of the rock; as a result of this decomposition new compounds will be formed, and these secondary products—sometimes hydrated silicates like zeolites, sometimes chalcedony and other forms of silica, sometimes, again, anhydrous carbonates like calcite—will be slowly deposited in the vesicular cavities of the rock, and may even permeate its very substance and be formed in its minutest pores.

In this case the relationship between the natural minerals and their modern representatives is so close that we are perfectly justified in applying our knowledge of the historical process to the explanation of the geological phenomenon.† But this is by no means always the case. When we have found how a certain compound, comparable in composition and in form with a natural mineral, may be formed artificially, it does not necessarily follow that we have learnt anything about the formation of the mineral in Nature. Art and Nature may have reached the same goal by totally different roads.

As an example of the danger of supposing that we have always

* 'Il est d'ailleurs possible que l'eau pure suffise souvent, pour produire des zeolithes,' Daubrée, *op. cit.*, p. 209.

† "Les briques, avec leurs boursouflures et leurs druses," says Daubrée, "imitent d'une manière suprenant les roches amygdaloïdes. Une telle identité dans les resultats décèle incontestablement de grandes analogies d'origine," *op. cit.*, p. 208.

hit on the natural process of mineral-making, let me revert for a moment to Pepys's experiment. The geologist would go far astray if he fancied that the explanation of the origin of pyrites suggested by this experiment was of universal application. Even without being so simple as to suppose that every mass of pyrites must needs imply the sacrifice of a hecatomb of mice, he would display but little sagacity if he assumed that organic matter of any kind had in general played a part in the formation of iron-pyrites. If he found pyrites crystallized in the chambers of an ammonite, it would be perfectly legitimate to conclude that it owed its origin to animal agency; but if he found the pyrites in the heart of a mass of granite he would have to look about for some other genetic process which should be in harmony with the conditions suggested by this new occurrence. In our laboratories we can usually form the same chemical compound in a variety of ways, and surely no one will deny to Nature an equal wealth of resource.

It is thus evident that it is not sufficient to have produced a given mineral artificially; in order that the synthesis may have geological value it is necessary to show that the combination of conditions under which the body in question was obtained is compatible with all the circumstances under which the corresponding mineral occurs in the field. The chemist will be listened to with respect only when he can show that he has satisfied the geological conditions of each case, and that his operations offer a fair analogy to those which we may reasonably suppose to have been at work in the economy of Nature.

Hitherto we have referred only to experiments which have been made accidentally and indirectly; but the genuine experimentalist works on more definite lines. Standing in front of a geological problem, and recognizing his inability to cope with it unaided, the geologist beckons to the chemist and the physicist to come over and help him. Strengthened by their aid, he sets to work in the laboratory, and endeavours to imitate by Art what is accomplished on an ampler scale in Nature, fixing his eyes on the famous aphorism of Leibnitz, so often quoted by experimental geologists, "Nature is only Art writ large."* In his attempts to reproduce artificially the phenomena of Nature the experimentalist may or may not be successful. But even his failures are not without

* "Neque enim aliud est Natura quam Ars quædam magna," *Protogæa*, ix.

value, though of a negative character, since they often serve to warn us that our hypotheses are on the wrong track.

As an illustration of the use of experiment in the verification, or the disproof of hypothesis, let us consider the attempts to reproduce Dolomite. For the best part of a century the origin of this rock has been the frequent subject of warm dispute, and the question has indeed raised some of the prettiest little storms that were ever brewed in the geological tea-cup.

At first sight it seems likely enough that this rock might be formed by direct precipitation. Its frequent association with rock-salt and gypsum suggests that it may have had a lacustrine origin, and if there were magnesian as well as calcareous rocks in the neighbourhood of an enclosed sheet of water the carbonates of magnesia and of lime might readily find their way into the lake. But in order that this plausible suggestion may find favour in the eyes of a geologist it ought to come before him supported by the credentials of experiment. When, however, Gustav Bischof, many years ago, applied himself to the subject, he found that on the evaporation of a solution containing these two carbonates, almost pure carbonate of lime was at first deposited, then the mixed carbonates were thrown down, and towards the end of the process little appeared but carbonate of magnesia. If, therefore, this were the method by which magnesian limestone had been formed, we should expect to find each bed underlain by a layer of limestone, and covered by a deposit of magnesite. But no general sequence of this character is observed, and consequently the hypothetical method of depositing dolomite from solutions in which the two salts co-exist, must—if Bischof's results are trustworthy—be dismissed as insufficient.*

But if we cannot deposit dolomite directly from solution, can we not cause its precipitation by double decomposition in certain chemical reactions? Here we turn with promise to the researches of Dr. Sterry Hunt, who, many years ago, suggested some very plausible views on this subject—plausible in so far that while perfectly satisfying the chemist, as having been verified in the laboratory, they presented no geological improbabilities. By the natural decomposition of various silicates containing soda—especially the soda-felspars which are readily attacked by meteoric waters—

* 'Chem. Geol.,' 2 Aufl., Bd. iii, p. 52.

carbonate of soda may be formed, and this salt carried in solution in streams would find its way to the sea, where it would encounter magnesian and calcareous salts, notably the chlorides. By mutual decomposition common salt and the carbonates of lime and magnesia would be formed, the proportion of magnesian salt being at first but small. Somewhat similarly when carbonate of lime acts on sulphate of magnesia the interaction yields sulphate of lime and carbonate of magnesia, and it seems likely that the latter might associate itself with carbonate of lime to form the dual carbonate, which, in this case, would be associated, as is so often the case in nature, with gypsum.*

A double decomposition is, of course, not so simple as a mere deposition from solution. Yet no adverse argument should be grounded on this fact, since it is a mere popular conjecture that Nature always works in the simplest possible manner. It is true that Newton said "Nature is pleased with simplicity, and affects not the pomp of superfluous causes."† But for all that, the seduction of simplicity has led many a philosopher off the right track; and the geological experimentalist should hesitate to dismiss a theory solely on the score of its complexity—or what to our simple and feeble understanding seems to be complexity.

The direct method of deposition or precipitation will probably explain the origin of certain dolomites, such as those of the Franconian Jura and the magnesian limestones of the Neocomian series in the south of France. But it would be impossible to admit the general applicability of such an explanation. Go, for instance, to the Eastern Alps, and you find yourself in the presence of a magnificent display of dolomites, to which such an origin can hardly be attributed. In the Triassic series of that region crystalline dolomite is developed on the grandest scale, forming those picturesque jagged-peaked mountains known as "The Dolomites." Von Buch—following the views of Arduino in the last century, and later of Heim—suggested that these rocks were originally normal limestones which had been metamorphosed by the action of magnesian vapours. Eruptive rocks, like melaphyre, containing magnesian silicates, are associated with the dolomites, and it was assumed that these rocks had emitted hot vapours,

* 'Chem. Geol.,' 2nd Series, xxviii, p. 170.

† 'Principia,' Bk. iii. *ad initium*, quoted by Jevons. *Op. cit.*, ii, p. 281.

which, permeating the limestone, had effected its dolomitization. Few, if any, geologists now cling to this hypothesis; yet it is worth pointing out that Durocher, as late as 1851, put the hypothesis to the test of experiment with positive results. He found that when fragments of limestone were heated in closed vessels with chloride of magnesium the limestone became partially dolomitized.* It may be admitted that such an action might serve to explain the formation of dolomite on a small scale in the immediate neighbourhood of a volcanic vent; but it is manifestly incapable of that wide application which the Tyrolese dolomites demand.

That most dolomite has been formed by the alteration of limestone in the wet way is a common belief, supported by numerous experiments. Bischof persistently advocated this view, and maintained that where dolomite occurred in association with igneous rocks, the metamorphism had been effected, not by means of magnesian compounds derived directly from the intrusive masses at a high temperature, but rather from solutions which had obtained their magnesian salts from percolation through these rocks.

Probably, in many cases, the rock was originally deposited as a slightly magnesian limestone. Indeed, Forchhammer's analysis showed that certain corals contained as much as 7·65 per cent. of magnesian carbonate; so that a coral-limestone may well be magnesian. Richthofen regarded the great mass of the Schlern Dolomite as the product of reef-building coral-polypes. In like manner the hard parts of many other marine organisms are found to contain more or less magnesia, and many limestones may thus incline towards dolomite by virtue of their organic remains. By percolation of magnesian solutions, the magnesia may become concentrated. Bischof concluded from his experiments that by the action of carbonated waters on a dolomitic limestone only carbonate of lime would be dissolved out, while the proportion of carbonate of magnesia increased. The experiments of Gorup-Besanez failed to corroborate this view; neither did the investigations of Doelter and Hoernes support Bischof's conclusions. According to the latter, most dolomites were formed by the action of the magnesian compounds in sea-water, chiefly the chloride,

* 'Comptes Rendus,' xxiii, p. 64.

upon marine limestones of organic origin soon after their original deposition.*

By the continued percolation of water holding in solution carbonate of magnesia, through an ordinary limestone, the magnesian salt may combine with part of the carbonate of lime, and form a double salt, while another part of the lime-carbonate is removed in solution. Every molecule of carbonate of lime removed has its place taken up by a molecule of carbonate of magnesia. But this vicarious action is not without its sensible effect upon the physical appearance of the rock. Élie de Beaumont calculated that the replacement is accompanied, in the case of a compact limestone, by a diminution of volume to the extent of 12 per cent. We should expect that a rock thus metamorphosed would exhibit the effects of such a shrinkage, and as a matter of fact many dolomites are characterized by a cellular texture. Von Morlot determined by experiment that in certain dolomites the cavities formed 12·9 per cent. of the entire bulk of the rock—a diminution curiously close to what theory anticipated. It may be that this is simply a numerical coincidence without significance; but it looks rather as though we had here lighted upon one of the rarest things in experimental geology—the quantitative verification of a hypothesis.

Experiments on the origin of dolomite, though by no means so satisfactory and decisive as many relating to the formation of certain other rocks, furnish sufficient illustration of the principal, yet not the only, use of experimental geology—namely, that of throwing light upon petrogenetic processes. The origin of rocks has engaged much of the attention of the experimental geologist in the past, and it is bound to engage more of his energy in the future. But petrogeny is after all only one department of our great subject.

Experimental geology may be regarded as being composed of two branches—the one analytical, the other synthetical. Of these two, the analytical, which is obviously the simpler, was developed earlier than the synthetical, and has naturally reached to a higher

* "Chemisch-genetische Betrachtungen über Dolomit," von Dr. C. Doelter und Dr. H. Hoernes, 'Jahrbuch der k. k. geologischen Reichsanstalt,' xxv, 3, 1875, p. 293-332. This memoir contains a good bibliography of the subject. The English reader will find an admirable summary of our knowledge of the origin of dolomite in Prof. A. H. Green's 'Geology,' Part I (3rd ed.), 1882, pp. 245-248, 408-411.

by Werner and his school. One of the gravest objections to Hutton's views on this subject was based on the observation that masses of mineral silicates on solidifying from a state of fusion usually assume a vitreous character. Hutton readily met this objection by explaining that the rocks in question when fused were buried at considerable depths, either in the earth or beneath the sea, and that the pressure to which they would thus be subjected must materially modify the structural character of the solidified rock. Sir J. Hall conjectured that pressure, by retarding the process of cooling, would allow a crystalline structure to be developed; a conjecture which he proposed to put to the test by fusing basaltic and other rocks, and observing the characters which the products presented under varied conditions of cooling.

It might naturally be supposed that Hutton would have been the first to appreciate the value of his friend's proposed experiments, especially as chemistry had always been one of Hutton's favourite studies. Curiously enough, however, he met the suggestions with a chilly indifference, and rather ridiculed the views of those who were disposed, as he phrased it, to "judge of the great operations of the mineral kingdom from having kindled a fire, and looked into the bottom of a little crucible." * The truth is, Hutton believed that the puny processes of the laboratory were so vastly inferior to those of nature that an appeal to experiment might so far fail as to bring his theory into ridicule, and thus play into the hands of his opponents.

Notwithstanding Hutton's lack of sympathy, Sir J. Hall fortunately persisted in his researches, though many of his experiments were postponed, and none of the results published, until after his friend's death. Dealing first with bottle-glass, Hall showed that on very slow cooling it solidified as a stony substance, but by re-fusion and rapid cooling it readily resumed its vitreous character. Thence he proceeded to experiment on various kinds of whinstone, performing his fusions in a black-lead crucible heated in a reverberatory furnace at an iron-works. In all cases the results were similar. Whenever the melted rock was rapidly cooled it became glassy, but when the solidification proceeded slowly its texture was stony and even crystalline.†

* Hutton's 'Theory of the Earth,' Vol. i, p. 251.

† "Experiments on Whinstone and Lava," by Sir James Hall, Bart., F.R.S. (Read March 5, and June 18, 1798), 'Trans. Roy. Soc. Edinburgh,' Vol. v, 1805, p. 43.

So thoroughly did Sir J. Hall believe in the geological value of chemistry that he says:—"While chemistry was in its infancy it was impossible that geology should make any progress; since several of the most important circumstances to be accounted for by this latter science are admitted on all hands to depend upon principles of the former." *

It was objected again to the Huttonian view of the origin of granite that where this rock had burst through limestone the latter had not suffered decomposition, whereas if the granite had been an igneous rock its heat must have expelled the carbonic acid from the limestone. To this objection Hutton had replied that under great pressure the decomposition might be prevented. Hall was anxious to put this view to experimental test, and began some researches on the subject in 1790. In deference to his friend's wish, these were discontinued; but in 1797 Hutton died, and the following year Hall resumed his old work. Something like 500 experiments—ingenious, troublesome, and even dangerous—were undertaken with the object of examining the behaviour of carbonate of lime when heated under pressure.† At length he found that powdered chalk when strongly heated in closed gun-barrels, instead of passing into caustic lime, became converted into a solid crystalline substance resembling marble. "This single result," said Sir J. Hall, "affords, I conceive, a strong presumption in favour of the solution which Dr. Hutton advanced of all the geological phenomena; for, the truth of the most doubtful principle which he has assumed, has thus been established by direct experiment." ‡

Hall's researches on the fusion of rocks led to experiments by Gregory Watt—the son of the famous engineer—a student of great promise, who passed away at the early age of 27. Young Watt melted a mass of Rowley Rag, weighing about 7 cwt., in a furnace at Birmingham, and made careful observations on the nature of the product, which were specially noteworthy, since they showed that under certain conditions of cooling a spherulitic structure was developed.§

* 'Trans. R. Soc. Ed.,' vi, p. 74.

† "Account of a Series of Experiments, showing the effects of Compression in modifying the Action of Heat," by Sir James Hall, F.R.S.Ed. (Read June 3, 1805), 'Trans. Roy. Soc. Ed.,' Vol. vi, 1812, pp. 71-185.

‡ *Op. cit.*, p. 175.

§ "Observations on Basalt, &c.," 'Phil. Trans.,' 1804, pp. 279-313.

On the Continent experiments on the fusion of rocks were made even before Hall's investigations, by Faujas St. Fond,* and subsequently by Spallanzani.† The brilliant Italian philosopher held original views on the nature of volcanic phenomena, and sought to illustrate them experimentally ; the effect of heat on the trachytes of the Euganean hills being the subject of an interesting investigation. He lays down the principle that a high temperature acting for a short time might produce the same effect as a moderate heat operating for a long period; and hence he feels justified in applying to the interpretation of certain natural phenomena the results of his experiments rapidly conducted in glass-furnaces. We are thus reminded of the saying of Paracelsus, quoted by Bacon :— "Vulcan is a second nature, imitating concisely what the first takes time and circuit to effect."‡ Dr. Reyer has pointed out that Spallanzani was greatly in advance of his day with regard to the explanation of volcanic phenomena. He regarded lava, for instance, as a mixture of crystals in a liquid base; and suggested that the movement of lava might be due to the presence of atmospheric air in the magma ; but finding difficulties in the way of accepting this explanation he was disposed to resort to the action of steam, and made experiments with the view of resolving his doubts.§

So far as our own country is concerned, the chemico-physical experiments of Hall and a few other early observers remained almost its sole contribution to experimental geology until the subject was taken up, many years later, by Dr. Sorby. His ingenuity of resource and originality of ideas, coupled with great manipulative skill, led him to devise and execute a series of fruitful researches—on the origin of limestones, the production of cleavage, the formation of ironstones, and other subjects—which saved the scientific reputation of Britain from being totally eclipsed by workers on the Continent.

Among Continental chemists who applied the resources of their science to the attack of geological problems a high place will be ungrudgingly assigned to the late Prof. Gustav Bischof, of Bonn. His famous treatise on Chemical and Physical Geology no sooner

* 'Mem. Mus. Hist. Nat.,' 1787, iii, p. 21.
† 'Viaggi,' iv, p. 17.
‡ 'Advancement of Learning,' Bk. iii, Cap. 3.
§ 'Theoretische Geologie,' von Dr. E. Reyer, 1888.

appeared than it attracted attention in this country, where few chemists were geologists and still fewer geologists were chemists. The Cavendish Society did useful work by issuing, between 1854 and 1859, an English translation of the original edition; and while our chemists thus showed their appreciation of the work, the Geological Society in due course stamped it with their approval by according to its author the Wollaston Medal.*

Daily familiarity with the ordinary operations of the laboratory led Bischof to believe that the potency of corresponding operations in Nature had been much overlooked; and the great object of his treatise was to show how various compounds corresponding with natural minerals could be formed by chemical reactions generally at ordinary temperatures. He saw that natural waters percolating through every cranny of a rock, and permeating its every pore, must tend to remove certain constituents in solution and to effect the alteration of most of the component minerals. Great use was properly made by Bischof of chemical pseudomorphs—those suggestive bodies in which the form of a mineral is retained after its substance has been either removed or transformed into another species. By the sagacious cross-examination of such specimens—supported by laboratory experiments—it is often possible to elicit a curious story of successive chemical changes involving solution, removal, alteration, and replacement; in fact, the proper interpretation of a pseudomorph often leads to a knowledge, not otherwise readily attainable, of chemical changes that have occurred in rocks. It is notable that artificial pseudomorphs, imitating certain natural bodies, have been prepared by Dr. Sorby, examples of which may be seen in the Museum of Practical Geology.

Always standing in dread of what he called the heresies of the plutonic school, Bischof was led to minimize the effects of thermal action; and even when the conditions under which a given mineral occurred suggested the intervention of great heat, he preferred to rely upon far-fetched wet processes. Believing that our knowledge of the effects of deep-seated sources of heat was speculative rather than positive, he persisted, wherever possible, in shutting his eyes to such agencies; and thus his theory became seriously incomplete. Nevertheless, his treatise still remains a

* Bischof dedicated the first volume of the second edition (1863) to the Geological Society of London in recognition of this honour.

repertory of information on chemical questions to which the student of geology may turn with unfailing confidence.*

The views of the Bonn professor were presented in so specious a manner as to captivate the younger students, who in some cases went even beyond their master in Neptunian sympathies. Friedrich Mohr, of Bonn, for example, wrote a clever work in which he quite out-Bischofed Bischof.† When it is said that in the year 1866, and living within sight of the old volcanoes of the Siebengebirge, Mohr seriously argued in favour of the origin of basalt as a precipitate from aqueous solution, it will be seen that the teachings of Bischof's school were not unalloyed with error.

Aqueous action at normal temperature will account for most epigenic changes in minerals and rocks; but without the aid of heat and pressure it is generally impotent to explain hypogenic operations. Geologists have come to see that the whole truth is not monopolized by either the Neptunist or the Vulcanist. It is rather in the union of their forces that we must look for victory in coping with most of the difficulties which the chemical geologist is called upon to face.

If Bischof and his followers ignored the action of heat, this charge cannot be brought against the French school of experimental geologists. In reviewing the history of this branch of science, we are struck by the conspicuous part played by the brilliant group of Parisian experimentalists. Some years ago the chemists of England and of Germany were startled by the boldness of a French professor, who commenced a treatise with the famous assertion, "La Chimie est une Science Française." But while such a dictum fell ill upon our ears, none of us will be slow to acknowledge that France, if not the birth-place, has for many years been the favourite home of experimental geology.

What other land can boast of such a list of workers in this

* "Bischof ist durch sein Lehrbuch der chemischen und physikalischen Geologie allerdings der Meister einer neuen chemisch-geologischen Schule geworden," B. von Cotta, in 'Die Geologie der Gegenwart,' chapter "Geologie und Chemie."

Vogelsang, who cannot be accused of too friendly an advocacy of Bischof's views, says: "Bischof bleibt für alle Zeit der Schöpfer der physikalisch-chemischen Geologie, nicht aber hoffentlich, der Meister," 'Philosophie der Geologie,' p. 119.

For an able criticism of Bischof's views, see the "Anniversary Address to the Geological Society," in 1867, by Prof. (now Sir) W. W. Smyth, 'Quart. Journ. Geol. Soc.,' xxiii, p. 58.

† 'Geschichte der Erde,' Bonn, 1866.

department as that which includes the names of Daubrée, Sénarmont, Ebelmen, Hautefeuille, Friedel, Bourgeois, and Fouqué and Lévy ?* It has even been attempted to prove that this aptitude for synthetical geology is closely connected with the national idiosyncrasies of the French. "Notre génie national," write MM. Fouqué and Lévy, "répugne à l'idée d'accumuler un trop grand nombre de faits sciéntifiques sans les coordonner, et si cette tendance nons entraine quelquefois à des hypothèses hasardées, elle a, d'autre part, le mérite de nous induire aux expériences synthétiques."†

Foremost among the experimentalists of France stands out the honoured name of M. Daubrée, for many years the head of the École des Mines in Paris. Daubrée's researches were communicated from time to time to the French Academy of Sciences in a long series of memorable papers, going back to 1841 ; but his general results were summarized in his Report on the Progress of Experimental Geology in 1867, and his collected researches were given to the world in 1876 in the form of a volume familiar to everyone who takes the faintest interest in the subject.‡

While admitting the important part played by water in the production of chemical reactions, especially as an agent in metamorphic phenomena, Daubrée always recognized the advantage of employing it at a more or less elevated temperature and under considerable pressure. Standing forth as the champion of *hydrothermal action*, we seem to see in his researches the Neptunist and the Vulcanist embracing each other. Having successfully overcome the initial difficulty of closing strong vessels containing superheated water—a difficulty which too readily passes into a danger—he performed a long suite of remarkable experiments which demonstrated how the chemical activities of water became exalted under the combined influence of heat and pressure.

Thus, glass exposed for two or three days to the action of superheated water suffered decomposition, and became transformed into

* The researches of these and other workers in the department of synthetical mineralogy are conveniently brought together and summarized by M. L. Bourgeois, himself a distinguished mineral synthesist, in the admirable volume which he has contributed to Fremy's 'Encyclopédie Chimique,' under the title of "Reproduction artificielle des Minéraux," Paris, 1884.

† 'Synthèse des Minéraux et Roches,' p. 5.

‡ 'Études synthétiques de Géologie Expérimentale,' par A. Daubrée. Paris, 1879.

a hydrated silicate resembling certain zeolites, while part of the silica set free encrusted the internal walls of the tube in the form of minute crystals of quartz, bearing the closest resemblance in form to certain natural crystals of large size, found, notably, in the Alps and in Brazil. Minute crystals of diopside, a variety of pyroxene, were also obtained by the decomposition of the glass—a notable result, inasmuch as it proved that an anhydrous silicate could be formed during processes in which water played a conspicuous part.*

It is true that the quartz and other minerals obtained by Daubrée were but small, usually microscopic; but size in such investigations counts for little. The same natural laws which mould a dewdrop give shape to a planet; and in like manner the forces which govern the production of a few grains of matter in a tube may be identical with those which form a similar product by tons in a mountain mass. A crystal of quartz no bigger than a pin's point, needing a microscope to render its faces visible, may have been formed by similar means to those which Nature has used in building up the huge crystals of the Alps, which may be measured by the foot and weighed by the hundredweight.

At the same time it is well for the experimentalist to be ever on his guard against the assumption that by increasing the intensity of any of the factors in his experiment—such as temperature, pressure, or strength of solution—he will necessarily obtain a result increased in the same proportion; in fact, the conditions of some geological phenomena are so nicely balanced that the increment of any element may disturb the entire economy and give rise to unexpected events. If the geological chemist obtains a given effect with a certain quantity of a particular agent he is not justified in hastily assuming that by increasing the quantity his results will necessarily be commensurately greater. It is always well to bear in mind the disappointment of Æsop's housewife, who, having supposed that if she gave her hen a double measure of barley, it would lay two eggs a day instead of one, found on making the experiment that the fowl grew fat and laid no eggs at all.†

Among recent labours of experimental geologists in France—or for the matter of that in any country—the most remarkable have been the synthetical researches of MM. Fouqué and Lévy, con-

* 'Géol. Exp.,' p. 175.

† Jevons, "Quantitative Induction," *op. cit.*, ii, 130.

ducted in the laboratories of the Collége de France.* In the course of these brilliant researches, commenced in 1878, all the principal types of basic volcanic rocks have been successfully reproduced.

Modern improvements in furnaces and blowpipes enable the operator in the laboratory to obtain exceedingly high temperatures under perfect control, and capable of being maintained constant for long periods. Ingenious means have also been devised for securing enormous pressure in sealed tubes, with a degree of safety formerly unknown. Availing themselves of the appliances thus placed at their disposal, and improving upon them, MM. Fouqué and Lévy set before themselves the task of reproducing the volcanic rocks belonging to the natural types which they had described in their classical work on Micrographic Mineralogy.

Andesite, labradorite, basalt, melaphyre, nephelinite, leucitite, leucotephrite, lherzolite, and ophitic dolerite—all these rocks have been artificially produced by fusion of either their component minerals or their chemical constituents. The chief features which differentiate their work from that of previous observers are, first, that the experiments were all made by dry fusion, without the intervention of water or of any fluxing agent; and, secondly, that the products were submitted to microscopic examination, with all the refinements of modern petrography, by acknowledged masters of the science.

Without entering into details, it may suffice to explain in broad terms, as an example of their general method, how they proceeded in this production of an artificial basalt. Starting with the constituent minerals of a basalt, rich in olivine, they took three parts of olivine, one of augite, and three of labrador-felspar, which they introduced, in a state of fine powder, into a platinum crucible, and heated in a furnace of peculiar construction. By fusion of these minerals a black, homogeneous glass was first obtained; but on subjecting this glass to a white heat for 48 hours the olivine, which is the least fusible constituent, separated in large crystals. A thin section of the product at this stage shows the crystals of olivine embedded in a brownish, vitreous magma. The crystals

* For the collected results see 'Synthèse des Minéraux et des Roches,' par F. Fouqué et Michel Lévy. Paris, 1882. An account of their researches was brought before an English audience by Prof. Renard in a Friday evening discourse, at the Royal Institution, May 18, 1888.

present all the microscopic characteristics of the natural mineral as it occurs in basaltic rocks, and are accompanied by small octahedra of magnetite and picotite.

The next phase of the operation consists in maintaining this product for 48 hours at a cherry-red heat, during which period a microlitic structure is developed in the paste. Examination of a section now shows that the large olivine-crystals of the first consolidation are surrounded by small lath-shaped crystals of labrador-felspar and by microlites of augite, while a second crop of minute granules of magnetite and picotite has made its appearance, these crystals being associated with a small proportion of amorphous matter, or interstitial glass, representing the residue of the original magma.

It will be noted that the essential feature of this synthesis, like that of MM. Fouqué and Lévy's other experiments, lies in the fractional method of crystallization due to the materials being subjected to successive reheatings or *recuits*. This represents what has actually occurred in Nature. In a basaltic rock the large crystals of olivine have probably separated from the primitive magma while in the interior of the earth. They are crystals of early consolidation, the chronological order of the successive crystallizations being made out by observing the mutual relations of the component minerals of the rock. The small felspars and augites in the basalt are of subsequent consolidation, having crystallized at a lower temperature, and probably after extrusion of the lava.

These synthetic experiments thus offer clear insight into the genetic history of a basalt; above all they prove that the rock may be formed by dry fusion, thus opposing the views so often put forward as to the part which water may have played in the process. If the presence of water is indicated by the analysis of a basalt we may regard it as accidental rather than essential, as secondary rather than primary, due, in fact, to the alteration which certain minerals have undergone, especially to the partial hydration of the olivine.

Although the synthetical experiments of MM. Fouqué and Lévy have been attended with marked success when directed to the reproduction of basic igneous rocks, they have been followed only by failure when turned towards rocks of acid type. The geological sphinx is still puzzling us with the great riddle of the genesis of

granite. Here the light of experiment utterly fails. It is true that all the typical constituents of granite have been obtained artificially, but we are by no means sure that the conditions under which we have formed them correspond with the conditions under which they have taken birth in granites. It is one thing to reproduce the constituent minerals of a rock; it is quite another thing to reproduce the rock itself. No eye can expect to see the deep-seated magma, which gives birth to plutonic rocks, or watch the slow processes involved in granite-building. But, though experimentation has not yet led us to the synthesis of such holocrystalline plutonic rocks, it is by no means certain that the path of investigation is absolutely closed against us. At present we are helpless, but not hopeless. Even now it seems as though experiment had cast an occasional side ray of light upon some of the difficulties suggested by granitic rocks.

Thus the petrologist has been puzzled by the fact that in many granites the quartz, though the least fusible of the mineral components of the rock, was evidently the last to consolidate, since it has moulded itself around the felspars, or, to use Prof. Rosenbusch's term, it is "allotriomorphic." Yet in other granites the quartz is "idiomorphic," that is, it asserts its own crystalline form and has consolidated before the felspars; while elsewhere, again, the quartz and the felspar appear to have crystallized simultaneously.

Possibly some light may be thrown upon these seeming vagaries by the experiments of Bunsen, who showed that when a solution of chloride of calcium was reduced in temperature the salt in some cases consolidated before the water, while in other cases the water solidified before the salt; the order of consolidation being determined by the relative proportion of salt and water in the original solution. Here, too, it may be fit to remark that Mr. Teall has called attention to the geological significance of the experiments of M. Soret and of the researches of the late Dr. Guthrie on Cryohydrates and eutectic mixtures.*

With reference to the origin of the plutonic rocks it must be admitted that much is still speculative. In following speculations, however ingenious, we are apt to feel that we are treading on stairs of sand, ready at any moment to crumble away. But when the waters of experimental verification have percolated through the sands of speculation the ground beneath our feet acquires firmness

* 'British Petrography,' p. 394.

and fixity. If some of our favourite theories are dissolved away others are consolidated, and we have the satisfaction of seeing what were previously mere probabilities crystallize into certainties.

Up to this point our studies have lain mainly in the domain of chemical or physico-chemical experimentation. But there is another region of experimental investigation which is even more inviting to the geologist by reason of its apparent simplicity. Every fault and even every bend in a stratum offers silent testimony to the operation of mechanical forces. What more easy than to imitate these on a small scale by means of mechanical aids?

Even before chemistry and physics were directly applied to the elucidation of geological phenomena it was sought to illustrate the position and accidents of the stratified rocks by mechanical experiments. Sir James Hall, who was a born experimentalist, and whose mind remained throughout life saturated with the belief that the experimental method was destined to play a significant part in the development of geological science,* had not failed at a very early period of his studies to undertake experiments of a mechanical character. His illustrations were simple, even to crudity, but they are of high interest from an historical point of view.

On examining in 1788 some highly contorted beds of killas on the coast of Berwickshire he conjectured that the folding might be due to the action of a powerful force exerted horizontally when the strata were in a plastic condition and yet subject to great superincumbent pressure. "This conjecture," said he, "no sooner occurred than I endeavoured to illustrate my idea by the following rude experiment;" and he then goes on to explain how he improvised an illustration by piling up layers of cloth loaded with weights, and subjecting them to repeated blows of a mallet delivered in a horizontal direction against boards placed vertically at the opposite ends of the series of cloths. The effect was to throw the yielding materials into plications similar to those of the contorted strata. The success of this simple experiment led him to construct a machine by which a set of beds of clay could be conveniently submitted to pressure.

* "Von Wenigen ist später die Bedeutung der Experimente für die Geologie so vorurtheilefrei aufgefasst worden wie von James Hall," 'Philosophie der Geologie,' von Dr. H. Vogelsang, 1867, p. 82.

In order to explain how the horizontal thrust was produced in Nature, Hall supposed that the beds of killas, originally deposited in a position approximately horizontal, had been invaded by igneous matter rising from below and forcing its way upwards through rents; the matter thus squeezed up would produce a lateral thrust, since the weight of the superincumbent strata—or the depth of sea if the deposits were in a submarine position—would prevent direct upheaval, and if, further, the strata were confined laterally they must accommodate themselves to the diminished space by becoming puckered.*

These early mechanical experiments, though highly suggestive, were but crude and incomplete. M. Daubrée, reverting to the subject 80 or 90 years afterwards, repeated the experiments in a more satisfactory form with improved appliances, and succeeded in throwing flexible plates of lead into complicated flexures resembling those of certain beds of coal, or even the schistose rocks of the Alps.†

In another series of experiments prismatic blocks of wax and other plastic materials were submitted to hydraulic pressure, and fissures were produced having a rough parallelism, comparable with that in a system of faults. Several layers of wax, variously coloured, were exposed to pressure until rupture occurred, and the surfaces of fracture sliding over each other presented an exact counterfeit of natural faults. It was found in bending a series of plastic layers that, when the plications became very sharp and the limit of elasticity was exceeded, the fold passed into a reversed fault, as was so well shown by Dr. Heim in his study of the Alps.

By subjecting prisms of soap to a crushing strain in a hydraulic press, Daubrée found that the separate pieces glided over each other and acquired curved, smooth surfaces similar to the "slip faces" observed in shales and often seen also in serpentinous rocks.

The labourers in the field of mechanical experimentation have not been few. Von Obermayer, for instance, has studied the flow of plastic clay, while Kick has experimented on the deformation of other substances. Nor should we overlook the curious experiments of Forchheimer on the effect of pressure upon masses of

* "On the Vertical Position and Convolutions of certain Strata and their Relation with Granite," by Sir James Hall, Bart. (Read Feb. 3, 1812), 'Trans. Roy. Soc., Edinburgh,' vii, 1815, pp. 79-108.

† 'Comptes Rendus,' lxxx, 1878, pp. 77, 283, 728.

sand, which having been satured with hot melted paraffin became consolidated on cooling, and thus retained the shapes which they had assumed under pressure.* But perhaps the most interesting of such researches to a geologist are those of Prof. Alphonse Favre. Visitors to the Natural History Museum at Geneva are familiar with his instructive models of mountain-structure in illustration of many features of the Alps. His method of procedure was simple, but ingenious. A sheet of caoutchouc was tightly stretched in all directions and the extended surface then coated with successive layers of differently-coloured clays in a pasty condition, the clays being confined laterally by wooden supports. On relaxing the tension the india-rubber resumed its original dimensions, carrying with it the adherent clays. The bands of clay—partly by adhesion to the caoutchouc and partly by the resistance of the lateral supports—became curiously folded and faulted, being thrown into a succession of wrinkles which mimicked with singular fidelity the structures common in mountain-ranges.†

In these experiments the contraction of the caoutchouc served to imitate the shrinkage of the earth's crust, consequent on the secular cooling of the nucleus. Some experiments made by Daubrée with the common caoutchouc balls, used as children's toys, were of a similar character; both series of experiments illustrating the formation of wrinkles in the crust of the earth which would follow if the contraction hypothesis were true.

In connection with this subject attention should be called to the ingenious experiments of Mr. Mellard Reade, which are detailed in his suggestive volume on "The Origin of Mountain Ranges." Layers of clay were placed in a "compression-chamber or contortion-box," and lateral pressure skilfully applied, when the strata were thrown into plications bearing a striking similitude to some of the features presented by mountain-structure. Curiously suggestive, too, is Mr. Reade's comparison between the general form of mountain-chains and that of the ridges produced in sheet lead by repeated expansions and contractions due to vicissitudes of temperature, as seen on the puckered lead from a house roof or the lining of a sink in a pantry.

Dr. Ricketts, in seeking to account for some of the contortions

* See "Molekularphysik," by Dr. O. Lehmann. Leipzig, 1888. Bd. i, p. 62.

† See 'Nature,' xix, Dec. 5, 1878.

of strata by the irregular pressure due to the local distribution of heavy matter on muddy deposits, has called experiment to his aid, and obtained results of a suggestive and significant character.*

Quite recently Mr. Cadell has carried out some experiments for the purpose of imitating the mechanical effects witnessed in the complex structure of the North-West Highlands of Scotland.† Horizontal strata of sand, loam, clay, and stucco were subjected to powerful horizontal pressure, when they became bent, broken, and faulted in a way that fairly imitated the structures of mountain regions where stratified rocks have been exposed to powerful horizontal thrusts. The well-known "fan-structure" of the Alps was imitated in these experiments, as also in similar investigations by Daubrée and other experimentalists.

Such experiments as those just recorded illustrate the effects of pressure, not only in deforming rock-masses by virtue of their plasticity, but in actual disruption of the mass, so that faults are produced as well as folds. It must be remembered that in like manner similar effects may be produced upon the constituent minerals of the rocks. These changes, being more obscure, are less easily followed; yet experiment has of late years shed much light upon the molecular as well as upon the molar changes that are brought about by mechanical agencies.

In 1867 Prof. Reusch, of Tübingen, published the results of his remarkable researches on the effect of pressure upon the molecular structure of crystals. His simple experiment, by which twin-lamellation is developed in a cleavage rhombohedron of calcite by means of pressure, is known to every student. These studies formed the starting point of a long train of investigations in Germany by such men as Gustav Rose, Baumhauer, Brezina, O. Mügge, von Ebner, Liebisch, and others. As an extension of Reusch's famous experiment, Prof. Johannes Lehmann embedded a crystal of calcite in metal, and then submitted the metal to blows of a hammer, when he found that the crystal, though maintaining its integrity, suffered deformation, became snow-white, and displayed throughout its mass twin-structure similar to that of many natural crystals which have been subjected to intense pressure.

* 'Brit. Assoc. Rep.,' Bath, 1888, p. 684.

† "Experiments in Mountain Building," by Henry M. Cadell, B.Sc., 'Nature,' March 22, 1888.

The geological bearing of such experiments is obvious. There seems but little doubt that in gneisses and crushed granites the pressure to which the rocks have been subjected has in many cases given rise to the twin-lamellation of plagioclase, and, probably, to much of the cross-barred microcline structure.

By subjecting cylinders of clear rock-salt to compressing forces Reusch found that the prismatic faces became striated perpendicularly to the direction in which the pressure was applied; they also became bent, and even cracked, and, under certain conditions, the molecules were made to approach each other to such an extent that the prism lost as much as eight per cent. of its original length. Similar deformation and compression have, no doubt, been brought about in the crystalline constituents of rocks in mountain regions. The microscope shows that the twin lamellæ of a plagioclase crystal in a rock may be bent, while the general state of tension in a mineral is, in many cases, optically attested by the phenomenon of undulose extinction. Experiment shows that if a piece of india-rubber be properly placed between crossed nicols and stretched, the state of strain is at once indicated; and in like manner the stresses which have operated on a squeezed rock may be indicated by optical evidence.

A short time ago Prof. Judd pointed out, with much clearness, the relation between the secondary twinning and the strained condition of a crystal. Thus, in the centre of a bent crystal of plagioclase, just where the flexure was greatest, the intersecting albite and pericline twin-planes were developed, but towards the ends of the crystal, where the strain was less, this structure died away. Moreover, the experiments of Prof. Judd have shown that by acting with acid on calcite crystals, in which twin planes have been artificially developed by pressure, solution is most easily effected along these secondary planes. In the crystalline constituents of rocks these planes of easy solution must be readily detected by the natural waters percolating through the rocks, and cavities are thus eaten out in definite directions. Into such cavities secondary products may be introduced, thus giving rise to the phenomenon of schillerization.*

Not only do the crystalline constituents of rocks offer evidence

* "On the Relations between the Solution-Planes of Crystals and those of Secondary Twinning," by Prof. John W. Judd, F.R.S., 'Mineralogical Magazine,' vii, No. 33, Dec., 1886, p. 81.

of pressure by their curvature, but the large crystals occurring in Nature present similar phenomena. Thus the prismatic crystals of tourmaline from Cleaveland, in Massachusetts, are not unfrequently bent as though they had been plastic rods, while in some cases the limit of elasticity has been exceeded, and the prism shows transverse fractures, which have been healed by deposition of cementing material, though not without displacement of the several parts. Curved crystals of quartz, too, are well known to collectors. But where such crystals occur in drusy cavities, where they have enjoyed freedom of development, the curvature can hardly be accepted as proof of pressure. Indeed, Breithaupt, referring to the curved quartz crystals of the Grisons, regarded the deformation as having been brought about when the crystal was originally in a soft, nascent condition, referring, in illustration, to the fact that in 1770 a druse of calcite was opened in a vein at Schemnitz, in Hungary, in which the incipient crystals were so soft as to yield to pressure by the nail, and even to retain, when solidified, impression of the epidermis of the finger which had touched them. *

Of late years, however, we have learnt that substances which appear to be extremely hard, and even brittle, may exhibit great molecular mobility. The most striking researches, now familiar to every student of science, are those of M. Tresca, who, in 1865, showed that masses of solid metal, under enormous pressure, could be squeezed through openings as though they were mere paste. Daubrée, quick to see the bearing of these researches upon geological phenomena, associated himself with Tresca in some remarkable researches. Employing the same hydraulic press which had been used to demonstrate the flow of solids, they subjected clay to violent compression. The plastic material was caused to flow through an orifice, and the cylindrical jet of clay so obtained exhibited a distinct schistose and concentric structure, resembling in section a dicotyledonous stem with its annual rings.

When the clay was mixed with mica and other foreign substances the regularity of the schistosity strikingly simulated the structure of certain foliated rocks. The deformation of fossils was also curiously imitated. Representations of belemnites, made of chalk, embedded in clay and in lead, were submitted to pressure in a hydraulic press, with the result that the pseudo-fossils were

* 'Paragenesis der Mineralien,' p. 11.

broken and the fragments elongated in a fashion very similar to that of the well-known fossils in the Alps.

In connection with the effects of pressure upon plastic materials the famous experiments of Dr. Sorby on the origin of slaty cleavage will at once suggest themselves. By disseminating scales of oxide of iron throughout a mass of pipe-clay and subjecting it to lateral pressure, he induced a fissile structure in the clay.* Dr. Tyndall, as is well known, induced cleavage in bees'-wax and other substances by means of pressure.

The artificial production of cleavage by pressure naturally suggests a reference to dynamic metamorphism, so far as it comes within the scope of experiment. Nearly half-a-century ago Mr. Darwin, on his return from South America, made the acute remark that cleavage and foliation may be "parts of the same process." While, however, the mechanical origin of cleavage was readily accepted, it was difficult to form a clear mental picture of the way in which dynamic agencies could induce the chemical changes involved in the production of new minerals. It was, however, shown in experiments by Dr. Sorby that pressure in most cases facilitates solution, and must, therefore, promote chemical activity.

There is obviously another way in which pressure may stimulate metamorphic action. By the mechanical energy exerted upon the rock, heat must be generated, and in this secondary manner chemical changes are promoted. The late Mr. R. Mallet carried out a large number of comparative experiments on the force required to crush equal bulks of different rocks, but in forming an estimate of the amount of heat evolved during the crushing he resorted to calculation rather than to experiment. † Daubrée, however, measured the heat developed by the friction of masses of clay and other rock-forming substances upon rotating discs of marble; and he concluded that where metamorphism was most marked, yet where no igneous rocks were found, the heat generated mechanically would be highly effectual in producing metamorphic changes — "La Thermodynamique qui à déja jeté si vive lumière sur divers phénomènes chimiques et physiques, devra porter aussi son flambeau dans la Géologie." ‡

* 'Edinb. New Phil. Journ.,' iv, 1853, p. 137.
† 'Phil. Trans.,' 1873, p. 147.
‡ 'Géolog. Exp.,' p. 470.

Bacon remarked that some men will attempt to build a ship with materials insufficient to construct a boat. Something akin to this is the amiable and pardonable fault of almost every scientific enthusiast. Mr. Mallet attempted the bold task of finding in mechanical action a sufficient source of volcanic heat, but though it is generally believed that his theory was insufficient for this ambitious object, it is nevertheless not to be despised, and Prof. Prestwich has very properly insisted upon its value in the general explanation of metamorphic phenomena.

While it has long been admitted that pressure will indirectly induce metamorphic action by generating heat, it is only quite recently that we have become aware of the direct action of pressure in bringing about chemical effects. Our knowledge of this subject is due to the remarkable experimental researches of Prof. Spring, of Liége.* The starting point in these investigations was the well-known phenomenon of regelation. If pieces of ice are capable of being united by moderate pressure why should not fragments of other solids admit of similar union under greater pressure? Much as a gas is liquefied by compression, so it would seem that a powder should be solidified. In either case the molecules are brought so near together as to come within range of their mutual attraction; and cohesion, more or less marked, must follow. Experiment demonstrated the validity of such reasoning. If the experiments are made under ordinary atmospheric conditions the air between the particles prevents intimate contact, and, moreover, when imprisoned between the compressed particles, it tends, on relief of the pressure, to expand and cause rupture of the solid. In order, then, to secure cohesion it becomes necessary to operate in a vacuum. The powders of metals are then consolidated into compact masses, but still more remarkable is the fact that a mixture of powdered metals may thus be converted into a true alloy. Amorphous bodies become crystalline under pressure, and mixtures react chemically if the specific volume of the product is less than the sum of the specific volumes of the bodies which enter into the reaction. In the case of metals it was found that the consolidation of the powder was a function of the hardness; the softer the metal the less the required pressure. As the hardness is generally

* "Récherches sur la propriété que possèdent les corps solides de se sonder par l'action de la pression," par M. Walth. Spring, 'Bull. Acad. Roy. des Sciences de Belgique' (2), t. xlix, 1880, p. 322.

diminished by heat, an elevation of temperature favoured consolidation. When prismatic sulphur was consolidated it passed into the octahedral variety, and a similar effect was obtained with plastic sulphur, the general rule being that the body submitted to pressure is converted into a denser variety.

M. Spring reminds geologists that a solid rock may be compared to a glacier. Just as a glacier is formed by the consolidation of flakes of snow, and the stream of ice is continually flowing as a solid, suffering rupture at one place and then undergoing recementation by regelation, so our solid stratified rocks result from the consolidation of grains of sand and mud, originally transported by water, consolidated and contorted by pressure, and broken and recemented again and again; the faults of a rock being comparable with the crevasses of a glacier.

The converse of these researches leads to some curious conclusions. M. Spring has remarked with much acuteness that if we could command sufficiently refined mechanical means we ought to be able to convert a solid into a gas by mere pulverization. In this connection it may be remarked that a mixture of finely-divided coal-dust and air will explode like fire-damp, the highly-comminuted coal here behaving exactly like a gas—facts established by the valuable investigations of Mr. W. Galloway, of Cardiff, who was good enough to act as our conductor during our visit to the South Wales coal-field last August.

M. Spring found that when peat was subjected to a pressure of 6,000 atmospheres it was consolidated so as to form a hard, bright block, with all the appearance of a coal, so that persons, not knowing its derivation, at once pronounced it to be coal of ordinary type. At the same time all organic structure had disappeared.

In connection with the origin of coal it may be well to recall the researches of M. Frémy, which showed that when vegetable substances—not organized, buf merely organic—were heated in closed tubes to about 3,000° C. they became converted into a black amorphous material, which was an artificial coal.* He, therefore, argued that in the formation of coal the vegetable tissues are generally destroyed, and the matter undergoes ulmic fermentation, the resulting product being then converted into coal by heat and pressure.

It is clear, however, from Spring's researches that the process

* 'Comptes Rendus,' lxxviii, 1879, p. 1048.

requires no great elevation of temperature if only sufficient pressure be applied. We have merely to suppose that the vegetable tissues were converted into a peaty mass by fermentation under water, and that this pulpy matter was transformed into coal by the simple pressure of the superincumbent strata.

Artificial anthracite was obtained many years ago by M. Daubrée by the action of superheated water on pine-wood. The resulting carbon was in a globular form, closely resembling the anthracite found with calcite and native silver in the gneissose rocks of the mines at Kongsberg, in Norway.* It had previously been shown by Caignard de la Tour that wood on exposure to heated water at a lower temperature than that at which Daubrée experimented was converted into a kind of lignite or brown coal.† These researches, however, are by no means so suggestive as the recent experiments of Spring, which offer a simple and rational explanation of the origin of coal.

The fact that under great pressure solid bodies may enter into chemical union, though directly opposed to the old chemical apophthegm, "*Corpora non agunt nisi soluta*," is evidently of the first importance to the geologist. It disposes at once of many of the difficulties under which chemical geology has hitherto laboured, and it offers experimental support to the hypothesis of dynamic metamorphism.

Into the details of that hypothesis it is beyond my province to enter. A concise and lucid explanation of modern views on the subject will be found in Mr. Teall's valuable work,‡ and in Mr. Harker's admirable Report on Cleavage.§ Nor should we omit notice of the budget of essays on the origin of crystalline schists,‖ issued by the International Geological Congress. As this obscure subject may be regarded as the great geological question of the day it was a happy thought of Mr. Topley's to secure its discussion before a tribunal at once so competent, so impartial, and so cosmopolitan as that of the recent Congress. The subject comes before us this evening only incidentally and in connection with experimental investigation. But it is, perhaps, permissible to remark that, looking at what has been done by so many eminent

* 'Géol. Exp.,' p. 177.
† 'Comptes Rendus,' xxxii, p. 295.
‡ 'British Petrography,' p. 416.
§ 'Rep. Brit. Association' (Aberdeen Meeting), 1885, p. 813.
‖ 'Etudes sur les Schistes Cristallins,' 1888.

workers in our own country and on the Continent, we seem to be approaching within measurable distance of a rational explanation of dynamic metamorphism.

Probably much that we desire as geologists to know will ever remain beyond the reach of the experimentalist,* and we must, therefore, be content to speculate where we cannot demonstrate. Speculation, when it carefully avoids running counter to observation, must always occupy an exalted position in geological philosophy. Adam Smith's famous definition of a philosopher as "a man whose trade is to do nothing and to speculate on everything,"† could hardly be applied to our philosophical geologists without the grossest libel, inasmuch as their speculation is legitimately confined to those regions which are inaccessible to direct observation and experimentation.

In advocating the claims of experimental geology this evening I trust that I have not been led to insist unduly upon its value, and to extol this method at the expense of other departments of investigation. Experimentation needs, in fact, to be guided in many cases by the hand of hypothesis. If we make an experiment arbitrarily we shall probably derive but little benefit from it, and may fail in attempting to apply our results. The more promising course is generally to picture to ourselves—after careful observation and deliberation—a definite line of action as probably the course which Nature has followed, and then seek by experiment to prove or to disprove our hypothesis. If Newton could glory in his famous saying, "Hypotheses non fingo," lesser luminaries find the formulation of a hypothesis to the advantage of their studies. "The torch of imagination," says Prof. Max Müller, "is as necessary to him who looks for truth as the lamp of study."‡ The healthy mind, ever anxious to penetrate the subtle nature of things, involuntarily seeks relief in the scientific exercise of the imagination. Prof. Blackie has well remarked that "Imagination

* Mr. A. Harker, in a very suggestive paper, "On the Physics of Metamorphism," recently published in the 'Geological Magazine' (Jan., 1889, p. 15), proposes the convenient term *Plutono-Metamorphism* to designate those profound changes which result from the conjoint action of an elevated temperature and an intense pressure; and he remarks that such action offers "a problem to which we can bring no direct experimental knowledge."

† 'Wealth of Nations,' Bk. i, cap. 1.

‡ 'Lectures on the Science of Language,' Vol. i.

is the enemy of science only when it acts without reason."* The one great point to be kept steadily in view by the geologist, as, indeed, by the student of any other science, is that speculation must be kept in its proper place, and never permitted for a moment to usurp the seat rightly occupied by other powers of investigation. The imaginative faculty which can create a rational hypothesis—that is, a hypothesis conformable to ascertained facts—thus becomes a quality of the first importance to the geological experimentalist. "The one great method of inductive investigation," said the late Prof. Stanley Jevons, "consists in the union of HYPOTHESIS AND EXPERIMENT."†

In now quitting the position to which I had the honour of being elevated by your suffrages two years ago, I am anxious to express my grateful appreciation of the manner in which I have been assisted in the management of our affairs by the officers and Council of our Association; and, while thanking them for their efficient co-operation, I desire also to acknowledge the courtesy, the support, and the indulgence which it has been my privilege on all occasions to receive from the general body of Members.

It becomes my pleasing duty to transfer my trust to the hands of one who is not only a valued personal friend of long standing, but who is among the most steadfast supporters of our Association. To Mr. Thomas Vincent Holmes we have been indebted again and again for papers read at our meetings and for guidance at our Excursions, while he has recently established further claims upon our gratitude by his labour in the preparation of the volume of Excursion Reports. With the accomplishments of a field geologist, resulting from his training as a former officer of the Geological Survey, Mr Holmes combines a peculiar geniality of disposition, which must contribute to the popularity of his Presidency. In committing the prime guidance of our business to him I feel confident that he will not only maintain the efficiency of the Association, but will materially advance its usefulness. To me, let me add on parting, it will always be a source of genuine pleasure to watch—and, if possible, to aid—the development and prosperity of the Geologists' Association. "VIVAT! CRESCAT! FLOREAT!"

* 'Self-Culture,' ed. 7 (1875), p. 13.

† 'The Principles of Science: A Treatise on Logic and Scientific Method,' 1874, Vol. ii, p. 157.

On the Geological History of Iron-Ores.

By W. H. Hudleston, F.R.S., Sec. G.S.

(Read March 1st, 1889.)

Introductory.

There is no intention on the present occasion of going very deeply into scientific questions, nor will it be possible within the limited time at our disposal to treat the matter at all thoroughly. A glance here and there at some of the most noteworthy developments of iron-ore is all that can be expected. In doing this we must avail ourselves of the assistance of the chemist in a few elementary matters, and we must also consult the statistics of the various mining records to enable us to arrive at some estimate of the nature and the quantity of iron-ore in the several formations. Beyond this, there is no intention whatever of treating the subject from an economic point of view.

Part I.

Definition of an Iron-Ore.

And first of all let us define what is an iron-ore. Without going into minute particulars we may say that an iron-ore is a mixture of iron oxide or of iron salt, or of both, with certain earthy or carbonaceous impurities. Hence an iron-ore will present every gradation from a highly crystalline body to an extremely earthy one, and its percentage of metallic iron may range from about 72 per cent. to any figure which the smelter deems worthy of his consideration—say about 30 per cent. Excluding the sulphur compounds, there are only four iron minerals of first class importance. These four are *Magnetite*, *Hematite*,* *Limonite*, and *Chalybite*.

The Four Iron Minerals

Magnetite (cubic) has an iron percentage of 72·4; oxygen 27·6. It consists of one molecule of protoxide of iron and one molecule of peroxide, and has the formula Fe_3O_4. Portions of this ore possess polarity and are natural magnets or "load-stones." G. 5.

Hematite (rhombohedral) has an iron percentage of 70;

* Or Hæmatite, not Hēmatite.

oxygen 30. This is the peroxide, or sesquioxide of iron, the formula being Fe_2O_3. Varieties are Specular Iron, Red Hematite, Red Ochreous Hematite, Argillaceous Hematite, etc. G. 4·5-5.

Limonite has an iron percentage of 60; oxygen 25·6; water 14·4. It consists of two molecules of peroxide of iron and three of water, and has the formula 2 (Fe_2O_3) 3 (H_2O). Varieties are Compact ore (Brown Hematite), Ochreous yellow ore, Brown clay-ironstone, Pisolitic and some Oolitic ores. Bog ore, Laterite, Limnite, etc., are closely associated. G. 3·6.

Chalybite (rhombohedral) has an iron percentage of 48·2; oxygen 13·8; carbonic acid 38. It consists of one molecule of protoxide of iron and one of carbonic acid, and has the formula $FeOCO_2$ ($FeCO_3$). Varieties are Spathic ore, Clay-ironstone, and some Oolitic ores. G. 3·8.

Iron in Kosmos.

In one form or other iron is a very abundant element; indeed, I strongly suspect that it is the prevailing element of our solar system. In the native state it exists as disseminated grains in basaltic and other rocks, and has been found in large masses in Greenland, where probably it has been derived from basalt which has been subjected to reducing agencies. Prof. Rupert Jones has recently called my attention to an article in 'Le Naturaliste,' 15th April, 1888, where a figure is given of a mass of scoriaceous rock, about three inches across, containing lumps and filaments of native iron. This mass was collected by Dr. Johnston Lavis from the summit of Vesuvius. If we are to take a hint from extra-telluric bodies the meteorites speak in favour of an abundance of iron in Kosmos, since one class, the sky-irons, consist simply of metallic iron alloyed with some nickel. Another class, the sky-ironstones, consist mainly of iron, whilst the third class, or sky-stones, consist of stony matter in which iron and kindred elements, such as magnesium, play a part not dissimilar to their functions in the more basic lavas of our own planet.

Iron Minerals and Silicates in Rocks.

If the deductions I have drawn from the proportion of iron in meteorites be correct, it follows that there must exist an

immense store of iron in the interior of the earth, whilst the portion which exists in the crust is comparatively small. There it occurs chiefly in combination with silica or as magnetite grains. It is not probable that any portion of the primeval crust of our globe is actually the same as the very oldest rocks known to the geologist, but these oldest rocks have been constructed out of the materials of the primeval crust, and they contain abundance of iron silicates. Moreover, from time to time throughout geological history there has been a tendency to a reaction of the interior upon the exterior, whereby immense quantities of fluidal rocks have been brought in proximity to the surface. These are the plutonic and volcanic rocks, many of which contain large stores of iron silicates together with what I may term primary magnetite and other iron oxides.

Before proceeding with the main argument, viz., the accumulation of iron-ores, it may not be unprofitable to direct your attention to some of these iron silicates, to their mode of occurrence in the crystalline rocks, and to their relation with the disseminated grains of iron oxides, more especially magnetite. The most abundant iron silicates are mica, hornblende, and augite. To these may be added the rarer, but still more ferruginous olivine and hypersthene of the ultra-basic rocks. Whilst the clays of the sedimentary beds are made up largely of fragmental felspar more or less kaolinized, and the sandstones chiefly of fragmental quartz, both clays and sands are enriched with iron by the iron silicates, already partially modified by chemical action. Some interesting experiments are recorded lately in the 'Transactions of the Geological Society of Edinburgh'* on the action of carbonic acid on these minerals. It was found, for instance, that muscovite, which is not a highly ferriferous mica, was not chemically dissolved, whilst biotite lost some of its ferric oxide and magnesia. Hornblende and augite decomposed at the same rate as biotite: they became hydrous, and lost by solution magnesia, lime, and iron. The felspars yielded more slowly.

Transparencies.

I will now proceed to exhibit by way of illustration a few

* Vol. v, Pt. ii.

rock-sections, the point being to demonstrate the occurrence of iron-minerals.*

Iron, Oxygen, and Carbon.

Starting, then, with the iron silicates and iron oxides, especially "primary magnetite" as the source of our iron-ores, if we wish to know how these are accumulated we must, first of all, study the peculiar relations of iron to oxygen, and, secondly, the action of carbon products upon these results. In the end we shall be driven to admit that a large proportion of our iron-ores are due to processes engendered by vegetable decomposition, such processes acting as collectors or accumulators of the ore itself. In the case of the large deposits of magnetite and hematite in the Archæan or very oldest rocks, their accumulation by organic agency may be open to doubt, since even if due to the action of carbonic acid, such carbonic acid may easily have formed part of the Earth's atmosphere in these early times.

It is now necessary to reflect a little upon the peculiar behaviour of iron with regard to oxygen and carbon. The whole process may be described as a battle between iron and carbon for a molecule of oxygen. This is admirably illustrated

* The following were exhibited on this occasion :—

1. *Olivine basalt* (Pl. II, Fig. 3).—Cut from a specimen in the possession of Mr. Geo. Smith, from the drift of Finchley. The structure here is partly ophitic, with a fair amount of lath-shaped felspars and but little augite; primary or idiomorphic magnetite very conspicuous. The olivine, though fresh, is cracked, and these cracks have strings of fine magnetite dust of secondary origin, either derived from the mineral itself or the result of infiltration.

2. *Hornblende-andesite* (Pl. II, Fig. 1).—From a slide in the possession of Dr. Hatch. The chief feature of interest here is the partial replacement of the edges of the hornblende crystals by secondary magnetite.

N.B.—It is said that in the formation of actinolite from hornblende, the change is accompanied by a copious separation of granular magnetite.

3. *Serpentine,* Cadgwith (Pl. II, Fig. 2).—Cut from the well-known black serpentine. See analysis by myself in appendix to Prof. Bonney's paper, "On the Serpentine, etc., of the Lizard District," 'Q. J. G. S.,' Vol. xxxiii, p. 925. Here the process of conversion from olivine to serpentine is accompanied by the separation of magnetite dust beginning in the centre of the fissures.

4. *Hematite in Serpentine.*—Also from the Lizard district, another case of serpentinized olivine where nearly the whole of the iron appears as indefinite blotches of hematite. The veins contain both magnetite and hematite.

5. *Nepheline Rock.*—Nepheline associated with ferriferous augite. There is a fine skeletal crystal of primary magnetite, and numerous radiations of magnetite disposed in accordance with some peculiarity of the nepheline.

6. *Paulite,* Banff (Polarized).—Labradorite and hypersthene with some ilmenite.

by what occurs during the formation of bog-ore. Iron as bicarbonate disseminated in the waters of a pond, on reaching the surface, seizes on an additional molecule of oxygen, in the proportion of two of iron to three of oxygen. This causes it to lose its carbonic acid, but being desirous of having a companion, the sesquioxide of iron thus formed immediately combines with water, forms a hydrate, and sinks to the bottom. Portions of such accumulations are from time to time redissolved owing to the abstraction of the extra molecule of oxygen by the carbon of decomposing vegetation. This extra molecule of oxygen helps to form the carbonic acid or other humus compound which dissolves the iron now reduced to protoxide. In this way the game of solution and precipitation is kept up indefinitely, and where the balance is in favour of precipitation an accumulation of ore will occur.

The main lesson to be deduced from these considerations is that the agencies of reduction by rendering the iron soluble endow it with locomotion, whilst the agencies of oxidation are amongst these which tend to arrest that locomotion and to fix it in one spot. Doubtless there are other causes besides oxidation, as, for instance, the loss of the second molecule of carbonic acid in the bicarbonate without further oxidation. In this case the iron will be deposited as carbonate and not as hydrated peroxide.

These points are well stated by Pumpelly, who observes that iron is a base with a strong affinity for the acids most frequently circulating in the upper crust of the earth, and especially for the humus acids and their ultimate term, carbonic acid. It also has a strange affinity for oxygen, and in the presence of this it forms the nearly indestructible, and in the absence of organic matter almost insoluble, sesquioxide. As sesquioxide, in the presence of organic matter, it provides the oxygen for decay, and its residuary protoxide is itself dissolved by the resulting organic acid and enters into circulation.

Colour of the Rocks.

It is not too much to say that the principal colouring matter in nearly all rocks is due to disseminated iron oxide, and it sometimes happens that the most highly coloured rocks are most deficient in workable iron-stone. We have a good instance of this in the variegated strata of the New Red Sandstone, a subject very exhaustively treated by Mr. Maw, of Broseley,

some years ago in the 'Quarterly Journal of the Geological Society.' He found that the colouring is effected by films both of the anhydrous and hydrated sesquioxides investing the individual grains of sand. In many of these cases of intense colouring it is the degree of dissemination rather than the amount of iron which produces such a striking effect. The intermediate colours are due to the blending of the anhydrous and hydrated peroxide. It is probably owing to the deficiency of organic matter in these red rocks that they remain red rocks still. They have been coloured in the first instance by solutions of ferrous carbonates and sulphates depositing the insoluble peroxide, and, for lack of reducing agents in sufficient amount, the iron of these beds has not been rendered soluble, and therefore remains disseminated instead of being concentrated. In clays and shales the iron is mostly ferrous, and the colour of these rocks is a greyish blue. The iron in this case is partly protected from removal by the comparative impermeability of clay. Most blue clays will contain iron in various forms to the extent of about four per cent. of the metal. A grey clay of the Coal Measures was found to contain FeO 3·88, FeS_2 1·716. Some of the Skiddaw Slates contain up to eight per cent. of ferrous oxide.

Mode of Deposition.

We must now proceed to consider the evidence afforded by the iron ores themselves as to the causes which have determined their deposition. And let it be remembered that there is one important difference between iron ores and the ores of the heavy metals generally, viz., that the former occur for the most part in beds which form part of a series, in the same way as do limestones, clays, and sandstones. It is true that there is also abundance of iron ore in mineral veins and "flats," but still the bulk of the iron ores must be regarded as bedded accumulations.

Statistics.

Since the more recent deposits are on the whole less obscure in their nature than the more ancient ones, it will be convenient to commence our study with the newest rocks and to proceed downwards in the geological scale. Before doing so I would direct your attention to a summary of the output of iron ores

in the early part of the present decade, as shown in the following table:—

THE WORLD'S PRODUCTION OF IRON-ORES IN 1882.

		Tons.
	Great Britain	18,622,000
	United States	10,080,000
	Germany	8,981,000
	Spain	5,510,000
	France	3,857,000
1881	Austria-Hungary	1,157,000
1880	Russia	1,128,000
1881	Sweden	910,000
	Other countries, about	1,500,000

We cannot help noting that our ferruginous little island accounted for more than one-third of all the iron-ore mined at that date, viz., six years ago. However, we have nothing to do with the economics of the question; what we are concerned with is the geological information which such a table helps to convey. In order further to test the case I submit a table of the iron-ores mined in Great Britain in the previous year, arranged according to their respective geological formations:—

IRON ORES RAISED IN GREAT BRITAIN IN 1881.

	Tons.	Tons.
A. Tertiary iron-ores (Ireland)		200,000
B. Iron-ores of Jurassic age—		
Cleveland	6,538,000	
Northants	1,270,000	
Lincolnshire	1,020,000	
Other districts	148,000	8,976,000
C. Iron-ores of Permian age—		
Lancashire	1,190,000	
Cumberland	1,615,000	2,805,000
D. Coal-Measure iron ores—		
England	2,540,000	
Wales	278,000	
Scotland	2,600,000	5,418,000
E. Iron-ores older than Coal Measures		238,000
Total in tons of ore		17,537,000

It is not possible to state exactly the nature of the ore in each case. Under E. most of the ores are crystalline. Some of the Cornish lodes yield fine crystals of hematite and göthite. Some of the fissures of the Carboniferous Limestone yield very pure spathic ores. The total, however, is very small, and the bulk of the ores mere vein-products. D. The iron-ores of the

Coal Measures are principally Clay-ironstone and Black-band ironstone, which must be classed as Carbonates, and also some brown ore, which must be classed as Limonite. C. The Permian ores of Cumberland and Lancashire consist almost entirely of Hematite. B. The Jurassic iron-ores are mainly Carbonates and Limonites.

Let us now turn to the United States by way of comparison, and here I am able to submit a very elaborate table by Mr. Pumpelly, which shows at a glance, by means of columns, the iron-ores mined during one year (1880) according to geological horizons and kinds of ore. Taking the Coal-Measures as our dividing line, we at once perceive that an enormous proportion of the iron-ore is found below these strata, whilst an extremely small amount is obtained from the beds above. In fact the conditions are exactly the reverse of what obtain in this country. At the same time it should be pointed out that, owing to the superior richness of the magnetites and hematites of the older rocks, the total yield of metallic iron for the two countries is by no means in proportion to the amount of ore raised.*

IRON-ORES RAISED IN THE UNITED STATES IN 1880.
AFTER PUMPELLY.

	Limonite.	Carbonate.	Hematite.	Magnetite.	Total (tons).
Tertiary ...	29,000	—	—	—	29,000
Mesozoic ...	—	74,000	—	—	74,000
Carboniferous...	30,000	824,000	—	—	854,000
Devonian...	39,000	—	—	—	39,000
U. Silurian	95,000	—	615,000	—	710,000
L. Silurian	1,626,000	—	323,000	403,000	2,352,000
Huronian...	332,600	—	1,574,000	161,000	2,067,600
Laurentian	—	—	24,000	1,800,000	1,824,000
	2,151,600	898,000	2,536,000	2,364,000	7,949,600

* The three years 1880-2 saw the maximum average of about 18,000,000 tons raised in the United Kingdom. Last year (1888) the iron-ore raised in

Part II.

We will now proceed more directly to the consideration of the "Geological History of Iron-Ores," commencing with the newest formations.

Recent Iron-Ores.

Everyone knows how quickly an iron pan forms towards the base of gravels and other porous beds under certain conditions of peaty soil and forest litter. It is hardly necessary to explain this further than to remark that the humus acids have been busily at work reducing and dissolving existing iron combinations. Such solutions are transported by underground percolation until arrested by an impervious bed or from some other cause, when they deposit an impure limonite which sometimes converts the base of a gravel into an iron conglomerate. This often happens in our Pleistocene gravels, and is well illustrated in the Bagshot district.

A very interesting instance of a recent deposit of iron-ore in large quantities is mentioned by Mr. Postlethwaite.* who says that when the Woodend Mine, near Threlkeld, was reopened, after having been closed for 13 years, it was found that where the mineralized water enters the level large masses of limonite had been deposited on the sides, and were hanging from the roof in the form of stalactites, filling up more than half the width of the level. In this case the source of the iron is attributed to the oxidation of pyrites.

Macadam† gives an interesting account of the deposits of meadow ore (limonite) now going on in Ross-shire. The Erradale deposit occupies a flat strath formed by the "red burn." Slabs several inches thick are thus being formed, and are used by the inhabitants for boundary walls. This is a really rich ore, some portions containing 50 per cent. of metallic iron. It is such meadow ores which probably afforded iron to the earliest metallurgists. Hence Linnæus, who was fond of a joke, named this species *Tophus*‡ *Tubalcaini*, in honour of the first

the United Kingdom had fallen to 14,166,000 tons, but the imports from foreign countries, chiefly Spain, amounted to 3,552,000 tons. (*Josiah T. Smith*: Address to the British Iron Trade Association, 1889.) At present I have no particulars as to the latest yield in the United States, but it is well known that the deposits there are enormous.

* 'Trans. Cumberland and Westmoreland Assoc.,' No. 11, "Mineral Springs near Keswick."

† 'Mineralogical Magazine,' Vol. vii, p. 72.

‡ A grain.

smith whom history has recorded, and also in allusion to the frequently granular character of the ore.

Lake Ores.

By far the most interesting of recent iron-ores are the deposits taking place in lakes, of which those in Sweden afford a notable example. In that country the rocks are generally well charged with iron silicates and other iron minerals, which undergo slight reduction and solution from the decay of forest litter, etc. In fact it is the old story on a large scale. The streams carry proto-salts of iron into the lakes, where the shuttlecock game between decomposing carbonaceous matter at the bottom and oxygen at the top results in the gradual accumulation of a large quantity of hydrated sesquioxide of iron (limonite) mixed with humus compounds, and too often with phosphates to a prejudicial extent. These ores may, in fact, be said to grow, and the proprietor can reap a crop, perhaps half a foot thick, every quarter of a century.

There is one point in connection with these lake ores of especial interest to naturalists, viz., to what extent diatoms are instrumental in the formative process. A general impression exists that they are in some way agents in this work. It was Ehrenberg who alleged that certain fresh-water infusoria or diatoms had the power of separating iron from water, and depositing it as hydrated peroxide in their siliceous coverings. *Gaillonella (Didymohelix) ferruginea* is believed to be more particularly active in this work. I have not been able to obtain an authentic account of this somewhat mythical diatom, but submit an enlargement of a drawing extracted from the Berlin Zeitschrift (1866) professing to represent this species. (Fig. 1.)

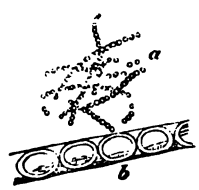


FIG. 1. *Gaillonella ferruginea*, Ehrenberg. *b* is magnified 2,000 times.

There are, no doubt, plenty of microscopic organisms, including diatoms, which are associated with lake ores, simply from

the fact of their remains being mixed with materials which go to form such ores. Also, it is by no means improbable that iron oxide, in some cases, replaces the opaline silica of the diatoms. But the question is—Do these diatoms really co-operate in the formation of lake ore in the sense of secreting from the water large quantities of iron? Or is it not rather that in their decay they contribute like any other group of organisms to the formation of compounds which are favourable to these accumulations. Samples of some of these ores abound with confervoid fragments, some of them coloured with oxide of copper or phosphate of iron, and many diatoms, such as *Spongolithis*, *Pinnularia*, *Navicula*, *Eunotia* occur. Nevertheless, it seems highly probable that lake ore could be formed without the assistance of a single diatom, and that the story of *Gaillonella ferruginea* secreting iron is more or less of a myth.

Referring for a moment to a much older formation, we might quote as a parallel case the encrinite iron-ore of the Lower Limestone Shales in South Wales. There is a statement in a well-known publication ('Iron-Ores of Great Britain') that "these [encrinites] seem to have the power of secreting iron to a great extent with the lime necessary for their support." On the other hand, Mr. Wethered ('Q. J. G. S.,' 1888, p. 190) remarks that the calcareous skeletons of corals and polyzoa in the Lower Limestone Shales are generally well preserved, but with the remains of encrinites the whole skeleton appears to be replaced by oxide of iron. However difficult it may be to account for this peculiarity, the replacement theory is to be preferred to the secretion theory, and this, I think, must be the explanation with reference to ferruginous diatoms in lake ore, if any such exist. It is only fair, however, to admit that certain heath plants do contain a considerable quantity of iron in their ash, and such plants also appear to favour the deposit of iron oxide. Hence it may be said if heath plants do this, why not diatoms likewise? *

* Since the reading of the paper my attention has been called to a pamphlet by C. W. Sjögréen 'On the Swedish Lake Ores' (Ekesjö, 1862, printed by A. Nilsson). He gives the following account of appearances at the bottom of a partially-drained lake:—

"And here a strange and wonderful spectacle was exhibited. On the bottom of these hollows, some of which were from 6 inches to 3 feet in diameter, ores of different shapes were lying motionless, on the top of which might be seen little beings of different sizes, some visible to the

Cascade Range.

It is mentioned by an American writer* that the basaltic rocks of the Cascade range, exposed to the immense rainfall and luxuriant vegetation of the Northern Pacific coast, have contributed to the formation of very extensive deposits of bog ore.

Tertiary Iron-Ores.

The same author says that similar deposits were forming also during the Tertiary period, as is shown by the Prosser Mine, near Portland, in Oregon. Here a body of limonite, from six to eight feet thick, still showing in places more or less the texture of bog ore, and containing roots and trunks of trees of a former forest growth, lies upon a bed of basalt, and is covered by many hundred feet of recent basalt. This contains up to 50 per cent. of metallic iron, with much phosphorus. Part of the bed is altered to a compact mineral like brown pitchstone, containing 30 per cent. of metallic iron.

Antrim.

The most noted Tertiary ores in the British Isles are those of Antrim, which, like the ores just mentioned, are also associated with basalt.

These deposits were described in the 'Q. J. G. S.' for 1869, when considerable difference of opinion was expressed as to their true origin. Their general position and nature may be inferred from Messrs. Tate and Holden's section on Island Magee. (Fig. 2. See next page). The ferruginous series is as much as 60 feet thick in some places, and is sandwiched between two masses of basalt, each about 300 feet thick.

No. 1 represents the hard columnar basalt of the upper series; at the base are a few inches of a steatitic (?) kind of rock.

No. 2. The upper portion of this is a pisolitic ore, some of

naked eye, and some so small as to be invisible without a magnifying glass, all actively engaged at their work, viz., to *spin* around themselves, like the caterpillar, their *metallic shell*." This apparent spinning he then proceeds to describe, and on the ground of these observations Herr Sjögréen was of opinion that the lake-ore is generated by these infusoria.

He professes to draw a distinction between the origin of "Lake-ore" and of "Bog-ore."

* Pumpelly, 10th Census Report.

the black pisolites having the appearance of graphite. These are more or less magnetic, many of them consisting chiefly of magnetite. This ore is rich in iron and nearly free from

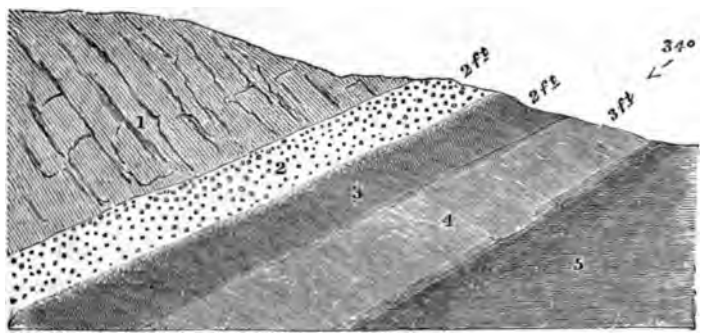


FIG. 2. Section at Belmford (after Tate and Holden).

1. Columnar basalt with 2 or 3 inches of decomposed rock below.
2. Pisolitic iron ore, 2ft. 6in., chiefly magnetite.
3. *Bole*—an indurated, red, ferruginous ochre, passing into and alternating with 3ft.
4. Yellow ochre, which graduates into
5. Blue lithomarge, base not seen.

phosphorus, but is often contaminated with titanic oxide; the lower part is an aluminous ore of considerable value, not so rich in iron, but equally free from phosphorus. Small partings and seams of a siliceous lignite are sometimes found in the aluminous as well as in the pisolitic variety.

Nos. 3 and 4 are red and yellow ochres.

No. 5. Lithomarge, a variegated argillaceous rock, with a predominating blue colour. This graduates downwards into a basalt exhibiting a concretionary structure, the outer coats not distinguishable from the lithomarge, whilst the kernel is a compact basalt. The lithomarge usually rests upon an irregular flooring of basalt, which in places is eroded into deep holes.

The source of the iron oxides in the ore bed is no doubt primarily the iron in the decomposing basalt, the ochres representing a sort of intermediate stage. The alumina is due to the same source. It only remains to suggest the agency of concentration. It is not unreasonable to suppose that these ores are of lacustrine origin, probably on somewhat different horizons. In other parts of the county an aluminous limonite in association with plants and lignite clearly point to the action

of decomposing vegetation—similar to what we have already seen. The present anhydrous condition of the pisolitic ore, and possibly, also, its freedom from phosphoric acid, is most probably due to the action of hot overlying basalt, which brought the original limonite into its present condition.

It is worth noting that when Tate and Holden's paper was read before the Geological Society there must have been a general belief in the ferruginating power of diatoms. Tate himself only once found diatoms of the *Coscinodiscus* type, and "not of the genera which form the bog ore." Hence it is evident he did believe in diatoms forming bog ore. In the discussion which followed the late David Forbes spoke of the pisolitic ore of the Swedish lakes as "still in course of formation by means of confervoid algæ," and Mr. Etheridge inquired if there were any traces of *Gaillonella*.

Iron-Ores of Cretaceous Age.

The Chalk of the British Isles does not, as far as I am aware, contain any noteworthy accumulation of iron-ore; but to the age of our Upper Chalk belongs the famous deposit of Somorrostro, near Bilbao, where red hematites, associated with some calcite, and practically free from phosphoric acid, occur between sandstones and limestones. The special features of this deposit are unknown to me.

The Lower Cretaceous series of our own country affords a few unimportant localities not much worked at present. The Tealby iron-ore occurs in Judd's Middle Neocomian, as does that at Claxby. The latter ore is described as a brownish-yellow hydrated peroxide, very oolitic, the grains being mostly of a shiny black, and hollow.* On this horizon we notice a feature very characteristic of the iron-stone series of our Secondary rocks, viz., the abundance of large Monomyaria, and especially of Pectens. At Tealby *Pecten cinctus* abounds. It is the same with the iron-ores of Jurassic age. In the Supracoralline deposit of Westbury are large specimens of *Pecten di-striatus*. The iron-stones of Dogger age, especially at Northampton, contain abundance of large Limas, whilst the Cleveland ore and its equivalents contain *Pecten æquivalvis*, which is perhaps the biggest of them all.

* Kendall, 'Iron-Ores of the English Secondary Rocks.'

Iron-Ores of Jurassic Age.

The deposits at Westbury and Abbotsbury between the Corallian and the Kimeridge Clay are of considerable interest, but not important in comparison with other ore beds of this system. Practically there are three horizons in the Jurassic rocks, which have recently yielded large quantities of iron-ore, the highest of these being the Yorkshire Dogger and its equivalents. This is mainly within the *opalinus* zone, and for the most part rests on the Upper Lias. The next is the Marlstone, or *spinatus* zone of the Middle Lias, in which occurs the Cleveland main seam. Thirdly, there is an exceptional development of iron-ore in the *semicostatus* zone of the Lower Lias at Frodingham, in Lincolnshire.

(a) The Dogger.

Situated at the junction of the Inferior Oolite and Lias, this ferruginous horizon can be traced throughout a large part of N.E. Yorkshire, where it is known as the "Top Seam." This is very unequally charged with iron, and is only worked when trade is brisk, but there are many features of interest to which I would briefly direct attention before proceeding to consider the Northamptonshire iron-ore, which is situated on the same horizon.

The Dogger in Yorkshire.

Without attempting to describe the features of the "Top Seam" in the districts where it has been chiefly worked, I may remark that the development of the Dogger at the Peak has the most interest for geologists. It there consists of a chocolate-coloured sub-oolitic irony grit, the series being about 30 feet thick, and it immediately underlies the carbonaceous shales and sandstones of the Yorkshire Lower Estuarine. The *Nerinæa* bed, which contains so many of the fossils of this horizon, appears originally to have been a marly grit. Now the shells are more or less ferruginated, and exist either as spathic iron or as limonite. These facts were pointed out by Sorby more than 30 years ago. Sometimes when the shell is very thick, as in the case of *Astarte*, an inner layer of calcite may yet be noticed. In the year 1874, being at that time unacquainted with what Sorby had written, I drew the attention of the Association to these facts, and arguing from what I had observed both in the Yorkshire and Northamptonshire Dogger, came to the conclusion that the

whole of this iron was the result of substitution, and that the element which had been mainly removed was calcium; in other words, that a sandy sub-oolitic limestone had become a sandy sub-oolitic ironstone.*

Rosedale Magnetic.

Before dealing with the structure of the Peak ironstone let us direct our attention to the celebrated Rosedale magnetic ore, which presents features of exceptional interest. There are two deposits of this peculiar ore, occurring in parallel troughs in the Upper Lias Shale. The horizon is that of the Blue Wyke Sands, and hence rather below the Dogger proper. Mr. Kendall, who is our chief authority, says that small denuded areas in the Upper Lias Shale of Yorkshire are not uncommon, and that they are frequently occupied by siliceous limestones of the Dogger series.

The ore is very oolitic and, when unweathered, strongly magnetic, owing to its large charge of magnetite, an unusual circumstance for ores of the Secondary rocks in England. This is probably due to the partial peroxidation of the carbonate in the oolitic grains, where the magnetite entirely resides. The unaltered blue-black ore contains :-

Ferric oxide	28 per cent	Iron 48 per cent.
Ferrous oxide	37 ,,	

It is, in fact, Mr. Kendall thinks, a compound of magnetite and clay ironstone. The section exhibited (See Pl. II, fig. 4) might in some respects pass for the section of an ordinary oolite, where there are concentric ova of fine granular matter in a paste, which is largely composed of calcite, the chief difference here being the absence of fibrous structure. This was probably a highly calcareous rock originally, remarkably free from grit, consequently the percentage of iron is now high. Though different portions of the mass yield varying results, the above percentage may be taken as a fair average. The interspaces consist mainly of carbonate of iron, intermixed with fine granular matter of the nature of mud (hydrous silicate of alumina). The subtranslucent granular matter in the interior of the ova is also probably of the nature of mud mixed with some ferrous carbonate. The richest part of the ore, therefore,

* 'Proc. Geol. Assoc.,' Vol. iv, p. 123, *et seq.* "Excursion to Northamptonshire."

resides in the outer part of the grains, which may be regarded as consisting of nearly pure magnetite. The calculated amount of magnetite is 40 per cent., and that of the ferrous carbonate 24 per cent. This still leaves about 9 per cent. of iron protoxide for combination with silica, phosphoric acid, etc. Several flakes of mica may be noted in the slide, whilst there is scarcely any quartz grit.

Peak Ironstone

We are now in a position to compare the rich Rosedale ore with a ferruginous grit of the Top Seam series from the Peak —a sample, in fact, of the true Dogger as there developed. In this slide the angular clear spaces are mainly sections of quartz grains, whilst the opaque portion represents a paste of limonite, in which they are embedded. But the numerous ill-defined ova show that this possesses oolitic structure, and when we examine the rock closely we find that greenish gray granules constitute a considerable portion of the mass. The case of the shells, before quoted, is proof enough of substitution, but in this case there has been secondary action, and much of the carbonate of iron has been oxidized to limonite, with possibly some admixture of hematite. Like the so-called Northampton Sand, and other gritty ores, oxidation is favoured by the highly granular character of the rock, just as it is checked in the closer-fitting particles of the more argillaceous ironstones. The question of the source of the iron will be discussed in connection with the Duston ore.

Northampton Ore.

Proceeding southwards, the Dogger is found to possess a varying charge of iron throughout the East Midlands, having been worked on a small scale near Lincoln, and at Cottesmore, in Rutland. In the county of Northampton the ore-bed, says Mr. Kendall, is of a quality suitable for metallurgical purposes over a very large area, and has been worked at many places.

There are probably no more interesting sections anywhere than those in the neighbourhood of Northampton, where the ore-bed in some cases is nearly 30ft. thick. It consists largely of limonite, and contains *en masse* from 25 to 40 per cent. of metallic iron. The lowest beds are very rich in phosphoric acid, and contain cores of greyish-green carbonate, mixed with

silicate. Some of them even have a bluish tinge, which may be due to the amount of hydrated ferrous phosphate. Although these lower blocks are not prized by the smelter, they are interesting, from a scientific point of view, as affording evidence of the origin of the Northampton ore. (Fig. 3.)

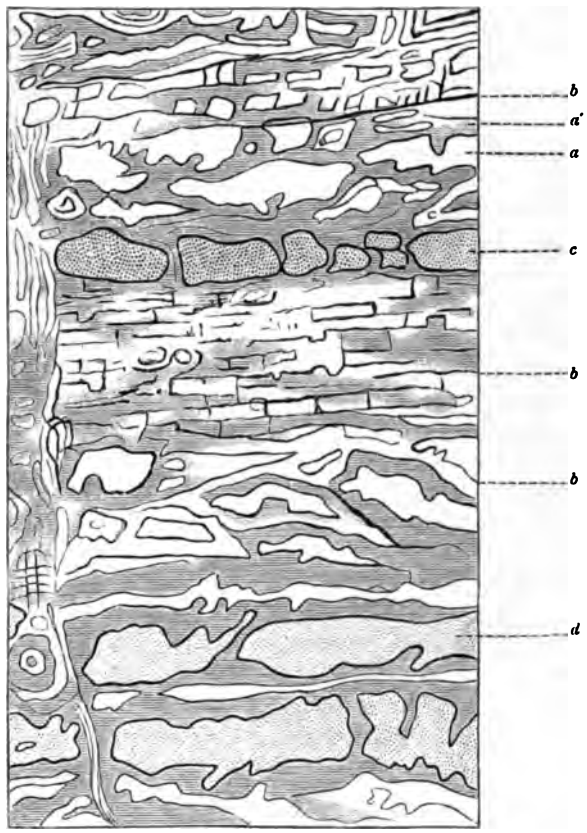


FIG 3. Northamptonshire Iron-Ore (after Maw).

a and a'. Friable portions, yellow to brown in colour, containing about 21 per cent. of Ferric oxide.

b. Hard brown strings, layers and shells of iron-ore, containing about 75 per cent. of Ferric oxide.

c. Nodules of compact Carbonate of Iron, containing about 80 per cent. $FeCo_3$.

d. Green ores, occurring near the base; mostly Carbonate, with some Silicate of Iron, and 2 per cent. of Phosphoric Acid.

This may be said to exist in three conditions—(1) as a brownish-yellow soft mass, full of oolitic granules, and containing a variable proportion of quartz grains. When the quartz grains predominate to any extent the ore is merely a ferruginous grit, like the specimen from the Peak. This portion of the ore contains about 21 per cent. of sesquioxide of iron, 1 per cent. of ferrous oxide, and 1 per cent. of phosphoric acid. Its colour and appearance are due to the admixture of disseminated limonite, with much earthy and marly matter. (2) The second condition is that of strings or shells of dark brown oxide; these consist of nearly pure limonite, and are, of course, very rich in iron, 76 per cent. of the sesquioxide having been calculated. (3) The third condition is that of the greenish-grey cores already mentioned. These represent the unoxidized residue of the rock: their structure being oolitic or gritty in variable proportions. These greyish-green layers are very much like the Cleveland ore both in composition and physical condition, being, on the whole, somewhat more sandy. A specimen analyzed by the late David Forbes was estimated to contain 40 per cent. of protoxide of iron, chiefly as carbonate, but also with much silicate and phosphate. The phosphoric acid alone was estimated at 2 per cent.

The conditions under which the Northampton ore occurs in the neighbourhood of that town are so well known that a study of them helps to throw considerable light on the origin of iron-ores of Jurassic age in this country. It should be borne in mind that the calcareous equivalents of this ore are worked as building stones, both at the Duston stone-quarry, and at Bass' pit, in Northampton. The species of fossils are identical, but their mineral condition is quite different. It is perfectly clear, therefore, that whilst some portions of the Dogger, in this district, have been ferruginated, other portions have not, or, at least, only to a small extent. The Dogger, whether calcareous or ferruginous, rests directly on the Upper Lias Clay; and above the ore and its calcareous equivalents occur a series of sands and sandy clays, with plant-remains, known as the Lower Estuarine of Northamptonshire. That the entire mass of the Northampton Dogger was originally a sandy oolitic limestone is pretty clear from the fact of the fossils being of the same kinds both in the ore and in the equivalent limestones. The relative position of the ore and limestone, with respect to the underlying Lias and

overlying Estuarine, is a further proof that both ore and limestone form parts of one series. It may, then, be taken for granted that no one doubts the Northampton iron-ore being the result of replacement, but opinions differ—1st, as to the mode of replacement; 2nd, as to the source of the iron.

Mr. Kendall has summed up the various opinions expressed on these subjects in his able paper entitled 'The Iron-Ores of the English Secondary Rocks.' He agrees in the main with the views announced by Sorby many years ago with reference to the origin of the Cleveland ironstone, and by myself more recently with reference to the Northampton ironstone, viz., that, in the first instance, carbonate of iron has replaced carbonate of lime. Carbonate of iron dissolved in carbonic acid, or, in other words, bicarbonate of iron, has permeated and saturated these rocks for a considerable period. These rocks were originally marly and arenaceous oolites, like so much of the Inferior Oolite elsewhere. Where the grains of quartz sand originally existed in the rock these still remain, and thus it happens that iron-ores on this horizon are often lean and sandy. This view of the case by no means harmonizes with the explanation offered by Professor Judd, who considered that the waters containing carbonate of iron dissolved portions of the "siliceous and other materials," which were in part redeposited in the rock in the form of oolitic grains. That the oolitic grains may, in some cases, be of secondary origin is very possible, but it is perfectly certain that the solvents in operation would attack carbonates more readily than they would silica and silicates. Hence it is only reasonable to suppose that all the carbonate of lime must have disappeared before any considerable quantity of siliceous matter could have been attacked. Judd has, no doubt, saved himself by making use of the phrase "other materials," but the prominence he gives to the solution of siliceous materials is decidedly misleading.

Oxidation of Northampton Ore.

The conversion of carbonate of lime into carbonate of iron implies a diminution of volume, or an increase of porosity, and this favours the second operation which the Northampton ore has undergone, viz., oxidation, whereby, through the action of surface waters the carbonate of the protoxide is converted into the ordinary hydrated peroxide, or limonite. In this way a

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peculiar distribution of the iron is brought about, which may be described as centrifugal. Argillaceous ironstones are, for the most part, protected from this secondary action by the inferior permeability of the material.

Source of the Iron.

We now come to the question as to the source of the iron in the so-called Northampton Sand. On this point we may freely admit that there has been more than one source, so that the various and conflicting views may all have some degree of truth.

Mr. Kendall, speaking of the iron-ore in our Jurassic rocks generally, considers that it has been derived from the interbedded clays, which were themselves made up out of the Permian and Trias of the north-west. He ought also to have added the Coal-Measure shales as a source of the Jurassic clays. He gives analyses, showing as much as 9 per cent. of protoxide of iron in a Lias clay, and about 7 per cent. of the combined oxides in Kimeridge clay from Westbury. Undoubtedly clays and shales contain a considerable amount of iron—about 4 per cent. in most blue clays. But the very fact that the iron is now there is more or less a proof that such massive clays have not been seriously leached by acid percolations. The beds which are apt to be thoroughly leached by organic acids are porous micaceous sands and their shales, such as those constituting the Lower Estuarine, which immediately overlies the ironstone in the neighbourhood of Northampton. The pale colour of these sands and shales tells of exhaustion, whilst the quantity of woody matter readily suggests the agent.

Some of you may, perhaps, have noticed how ferruginous quartzose sand is rendered colourless round decaying roots. It has been proved that the action of a root one-sixth of an inch in diameter whitens the sand to a distance of from one to two inches round it. This, of course, means the removal of the iron, probably as ferrous carbonate. I merely quote this as a sample of the nature and not of the extent of the agency. The amount of iron removed will depend largely upon the permeability of the beds. But whether from sands or clays, or from both, the motor in all cases must have been the products of organic decay, which, rendering the iron soluble by reduction, also supplied the carbonic acid which combined with and con-

veyed the individual molecules of iron from point to point until they found a suitable resting place. Hence it was the decay of life, and mostly of vegetable life, which set the machinery in motion, and thus the study of Natural History becomes in a way connected with such phenomena as the aggregation of iron-ores.

(b) Marlstone Series.

By far the most important development is the Cleveland ironstone.

Cleveland Iron-Ore.

The problem of the origin of the large charge of iron in the deposits of the *spinatus*-zone in Cleveland is less clear. There is no necessity for me again to insist upon the replacement theory. Practically everyone is agreed as to the introduction of iron by replacement subsequent to the formation of the rock. I must remind you that the Cleveland main seam has an extent of between 300 and 400 square miles, but that it is only the north-eastern part of the area which contains really good ironstone. The ore is usually rather thickly bedded, and towards the base has a somewhat greenish-grey tinge. Except at the outcrop the ore is mainly in the condition of ferrous carbonate, with a small admixture of the peroxide. Silicate of iron is present, especially in the granules. The structure is occasionally oolitic, the ova being very small, but much has simply the appearance of a mudstone. Organic remains are abundant, and *Pecten æquivalvis* is especially characteristic of the horizon both in Yorkshire and elsewhere. The abundance of animal matter is, no doubt, one cause of the large charge of phosphoric acid in the stone.

Analysis shows that the main block of the Eston ore contains only a trace of lime, whilst there is 2½ per cent. of phosphoric acid. In this case the charge is equal to about 35 per cent. of metallic iron. Taking the average of Cleveland ore, the earthy constituents amount to about 28 per cent. of the whole in the following proportions – silica 11½, alumina 8½, lime 5, and magnesia 3 per cent.* Much of this silica exists in a somewhat soluble condition, and it has been found that the small oolitic concretions, or fig-seed-like grains, after parting with their carbonic acid, yield a skeleton of silica, which readily dissolves

* Kendall, *op. cit.*

in caustic potash. It is quite possible that the agencies which supplied the charge of iron may at the same time have introduced a certain quantity of "soluble" silica, since the products of decomposing vegetation are known to have the power of dissolving silica to a considerable extent. On the other hand, this excess of "soluble" silica may be due to silica-secreting organisms which have been buried in the bed itself, though this is the least probable supposition. We shall see further on the remarkable connection which exists between dissolved silica and iron-ores in the case of the ferruginous schists of the Lake Superior region. In an abstract notice of these schists, etc., in the 'Mineralogical Magazine,'* Mr. Teall alludes to the silica in the oolitic grains of the Cleveland ore.

Occasionally these granules favour a partial oxidation, and thus we find small quantities of iron oxide deposited concentrically. The transparency (Pl. II, fig. 5) shows this feature, but the opaque granular mass at the corner of the slide better represents the bulk of the ore, which may be regarded as a massive and earthy ironstone, which was originally a marl or marlstone rock, like so much of the *spinatus*-zone in other parts of England. This zone is also ferruginous in other places, as at Caythorpe, in Lincolnshire, Holwell, in Leicestershire, Adderbury, on the borders of Oxfordshire and Northamptonshire, and Fawler, in Oxfordshire. But this is nothing compared to the enormous extent of the ferruginated area in Cleveland, and some explanation of this peculiarity may be demanded.

After what has been said with regard to other iron-ores, I need scarcely dwell upon the subject of leaching by means of organic acids as a process for conveying solutions of iron to beds affording facilities for substitution, whereby iron replaces some other element, generally calcium. But, as before stated, the source whence the iron of this horizon was derived is much less clear to my mind than in the case of the Dogger ores. There, in the majority of cases, the requisite machinery is supplied by an Estuarine series above. Mr. Kendall remarks that, usually, where the Dogger series is highly ferruginated the Marlstone series is not, and *vice versâ*. In the case of the Cleveland ore, he is disposed to look to the Upper Lias Shale as the source of the iron. Undoubtedly the Upper Lias of Yorkshire is ex-

* Vol. vii, p. 236.

tremely rich in iron, but this looks as though its beds had not been leached to any great extent for the benefit of other horizons. Still, the Upper Lias may have been so rich in iron as to have supplied the materials for the ferrugination of the Cleveland main seam without evincing many symptoms of exhaustion. The abundance of wood in some places rather favours the notion. At the same time, there is just the possibility that a large portion of the iron in the Cleveland main seam has been derived from beds of an estuarine character, which have either been removed, or are at present inaccessible to observation.

(c) *The Frodingham Iron-Ore.*

I must do no more than allude to the very interesting development of ironstone in the *semicostatus*-zone of the Lower Lias at Frodingham, in Lincolnshire. This consists of rather thin-bedded alternations of iron-ore (limonite) and ferruginous limestone, and affords good evidence of the truth of the replacement theory.

Iron-Ores of Permian Age—Hematites of Cumberland and Lancashire.

If we continued to adopt the order of geological position merely, the ironstones of the Coal-Measures would next come in for consideration. But the deposits to which I will now draw your attention, although they lie below the Coal-Measures, are mainly of Permian age, and ought to be considered in connection with that formation.

To Mr. Kendall's admirable papers we are indebted for most of our knowledge of these important iron-ores, which are found in the Eskdale Granite, the Skiddaw Slate, and Coniston Limestone, but principally in the Carboniferous Limestone. It is the latter only which we need consider, and I will direct your attention principally to the Hematites of West Cumberland.

Structure of the District.

A brief summary of the local geology may be useful. In that district the Carboniferous Limestone series rests transgressively on the older rocks. It consists of alternations of

limestone, sandstone, and shale, and in the Whitehaven district the number of limestones is six. These contain the bulk of the hematite. In the overlying Millstone Grit there are merely strings of hematite running up into it from the Top Limestone. The Coal-Measures, 1,100 feet thick, are made up of alternations of sandstones and shales of the prevailing dark colour, amidst which occur numerous bands of fire-clay, coal (26 seams), and clay-band ironstone.

The Upper Coal-Measures are apparently represented by a deposit known as the "Whitehaven Sandstone," which is alike unconformable to the main Coal-Measures below and to the basal Permian breccia above. It is important to note the existence of a bed of hematite in connection with red shales in this Whitehaven Sandstone. On the other hand, the basal Permian breccia contains iron gravel derived from the denudation of rocks containing hematite. These facts appear to fix the date of the ore deposits as between the end of the Upper Coal-Measures and the beginning of the Permian.

Mode of Occurrence.

The hematite occurs in all the six beds of limestone, but the deposits are most numerous in the first and third limestones. Their form is variable, being sometimes bed-like, sometimes vein-like; elsewhere filling dish-like hollows in the limestone immediately below the drift.

The bed-like deposits occur mostly in the first or Top Limestone. The Parkside iron-ore deposit is an excellent example. This extends over an area of thirty-four acres. The roof is of Millstone Grit, which is even and regular, whilst the sole of the ore, which rests upon Carboniferous Limestone, is subject to such undulations that its thickness ranges from 40ft. and upwards to as little as 4ft. In this case it is only the upper part of the Top Limestone which has been completely ferruginated. In another locality (Bigrigg) it is the lower part of the limestone which has been ferruginated; consequently the roof is uneven, whilst vein-like extensions of hematite pass upwards through siliceous portions of the limestone.

All the most important deposits of the Whitehaven district are by the side of faults, and this brings us to the consideration of vein-like deposits, such as those of Salter Hall and

Eskett mines, as depicted by Mr. Kendall. (Fig. 4.) This section almost tells its own story. Here there is a combination of the vein-like deposit and the bed-like deposit, and we

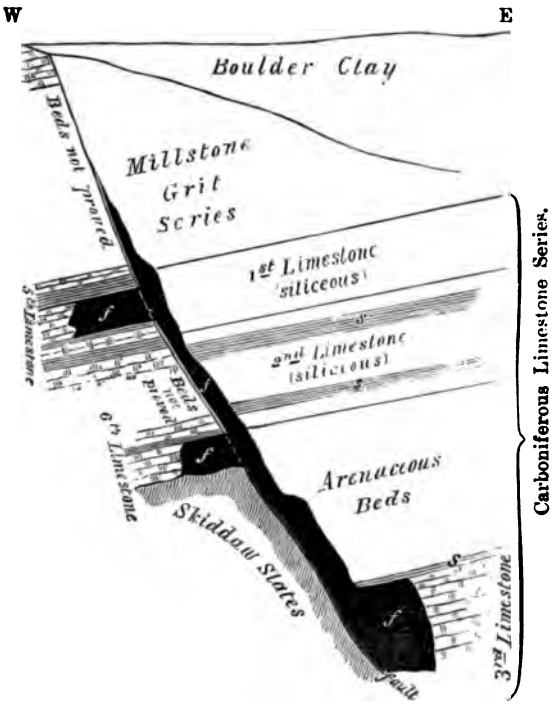


FIG. 4. Salter Hall and Eskett Mines, Whitehaven (after Kendall).

f. Hematite. *s*. Shales.

have no difficulty in understanding how the process of ferrugination is dependent upon faulting. This section also helps one to understand the geology of the district.

Composition, etc.

As a sample of the composition of West Cumberland hematite, the Salter Hill ore contains the following:—

Fe_2O_3	... ...	86·37 per cent.
Al_2O_3	... ...	1·21 ,,
SiO_2	... ...	9·56 ,,
CaO. aq. etc.	... ...	2·57 ,,
		99·71

This yields $60\frac{1}{2}$ per cent. of metallic iron, and there is only $\frac{3}{10}$ of phosphate of iron. The kidney structure so often seen is formed in open spaces in the interior of the ore called "loughs." Quartz and other minerals are also abundant in these "loughs." Much of the limestone is in the cherty condition known as "whirlstone," so that siliceous matter may be said to abound in connection with these West Cumberland ores.

It is worthy of notice that when the ore is in contact with either shale or sandstone, there is a distinct line of demarcation between the ore and the rock. This is rarely so when it is in contact with limestone or "whirlstone;" in this case the ore and the stone are grown together, and the passage from one to the other is by regular gradations. Another point of importance to be noted as bearing upon the question of the mode of formation of the ore is the occurrence of partings and nests of shale. In many cases such shale partings may be traced into the adjacent limestone, showing that all originally formed part of one series, and that the shale has been only slightly affected by the agencies which changed the limestone into ironstone. Mr. Kendall appeals to these cases of shale partings in the ore as conclusive proof that the hematite could not have been deposited in caverns, since this would imply the stretching across such caverns of thin beds of shale—an obvious impossibility. There can be no other explanation than that of replacement, and this is further exemplified by the presence of corals of Carboniferous Limestone species in the hematite ore.

Summary of Facts and Conclusions.

Briefly, then, we may sum up what may be regarded as more or less certain with regard to the history of the hematites of Cumberland, and presumably of Furness.

1. That the ore bodies are the result of the replacement of carbonate of lime by what is now hematite in portions of the Carboniferous Limestone series.

2. That the evidence is unfavourable to the supposition, maintained by some, that the hematite has been deposited in caverns and open fissures.

3. That faulting has greatly determined the position of the deposits.

4. That the ferrugination took place between the period of the deposition of the "Whitehaven Sandstone" (Upper Coal-

Measures) and the basal Permian conglomerate, *i.e.*, in the interval between the close of the Carboniferous and the beginning of the Permian.

Source and Mode of Introduction of the Iron.

The original source of the iron and the mode of its introduction are much less obvious. Of course the iron must have been in a state of solution, but whether as perchloride or bicarbonate, or in any other soluble combination, is not so easy to determine. Mr. Kendall, as quoted by the late Mr. J. A. Phillips, suggested the Coal-Measures as the probable source from which this metal originally came. He further remarked that the sandstones and shales belonging to that formation contain a large percentage of iron. Since these rocks probably at one time everywhere overlaid the Carboniferous Limestone of the hematite districts, he thought it not improbable that a large proportion of the iron in the limestones had been the result of the percolation of carbonated waters through super-incumbent beds. There can be no doubt that the Coal-Measures constitute an enormous store-house, both of iron-ore and of disseminated iron, as all estuarine deposits must do upon the principles already laid down in this paper. It is highly probable that the "churns" of brown hematite (limonite) in the upper beds of the Carboniferous Limestone of the Forest of Dean originated in this way. But in Cumberland we have to deal with red hematite, or anhydrous peroxide of iron, and the origin may possibly be different.

On the whole, Mr. Kendall now prefers what he calls a volcanic origin for the original iron salt. The replacement, it is true, is due to percolation from above, as is shown by the gash-like form of the veins, the ore generally becoming less and less as it goes deeper. But he considers that perchloride of iron was introduced in the gaseous form through the moving fractures of that uneasy period, and was dissolved in the waters of the "reddened Permian sea." Such irony water would then circulate freely in the Carboniferous Limestone along lines of faulting, but not otherwise. Hence, where there is no faulting there is no iron-ore.

In concluding this subject I am inclined to believe that the temperature of the solution, whether perchloride or bicarbonate, was high; partly because the ore body is now anhydrous, and partly because of the abundant deposit of rock crystal in

association with some of this ore. These facts rather point to hot springs, but beyond this I venture on no conjecture.

Other Permian Ores.

Although there is no time to deal with other iron-ores of Permian age in this country, we must bear in mind that the Permian horizon is essentially a ferruginous one. Fossiliferous hematite nodules are by no means rare in the Permian breccia of Leicestershire (Gresley, 'Mid. Nat.' ix. 1886). There is a remarkable instance of a compact hematite ore resting unconformably upon dolomitic limestone of the Carboniferous series at Mwyndy in South Wales. The ore itself is stated to be of Permian age; and a section is given in the 'Iron-Ores of Great Britain.'

Iron-Ores of the Coal-Measures.

We now come to the consideration of the Clay-ironstones of the Coal-Measures, with which must be included those of the shales in the Millstone Grit and the Yoredale series. The subject is so vast that it is impossible to give it adequate treatment if we are even to glance at any of the older formations. The question of concretionary action is one which, alone, might occupy an evening. The solid sheets of argillaceous ironstone, sometimes continuous over large areas, and elsewhere represented by nodules abundantly spread over plane surfaces of equal dimensions, are well known to the inhabitants of South Yorkshire and Derbyshire.

In many cases it seems to me that these bodies are not the result of replacement, but are original concretions in strata where carbonate of iron was more plentiful than carbonate of lime. The usual process of all "estuarine" beds, such as those of the Wealden in Sussex, or the Lower Oolites in East Yorkshire, was here effected on an immense scale. An abundant supply of decomposing carbonaceous matter yielded solvents such as I have before described, which served to leach the more permeable beds. It is not at all improbable that some of these clay-ironstones owe their existence, in the first instance, to lagoons or slight hollows in alluvial flats where peaty matter accumulated, though not in sufficient quantity to form a good coal. But it has been pointed out that the phenomena of coals, especially gas-coals, blackband-ironstones, and ordinary clay-ironstones, seem to wait upon each other very much. I merely

quote this as a suggestion, and pass on to the consideration of other formations.

Iron-Ores older than the Coal-Measures.

In the United Kingdom there are no ironstones largely worked in beds below the Coal-Measures except those of Permian age, which have been already noticed. But many interesting iron-minerals are obtained from these older rocks, such as the stalactitic limonite of the Forest of Dean, locally known as "brush ore." The well-known ironstone lode near Lostwithiel, in Cornwall, contains crystallizations of remarkable interest. Small hand-specimens exhibit hematite, göthite, and limonite in such close proximity that an excellent opportunity is afforded for comparing these three oxides. The Devonian rocks generally contain considerable quantities of hematite, chiefly in association with limonite and spathic ores. Hence it is by no means intended to imply that the older rocks in the United Kingdom are devoid of iron-ores. Yet a glance at the Table of statistics (*supra*, p. 110) shows that, as compared with the formations already described, they do not tempt the iron-miner to any great extent.

American Iron-Ores.

In America the case is quite different. In that country big things are, of course, the order of the day. But their "iron mountains," as well as the more ordinary deposits, occur in rocks which are certainly older than the Coal-Measures, and are for the most part of high antiquity. The so-called Archæan rocks contain a large proportion of the iron-ores now mined across the Atlantic, whilst the formations above the Coal-Measures, as we have already gathered from an inspection of the Table, contribute next to nothing. Omitting the clay-ironstones of the Carboniferous in America, I will endeavour to give a very brief sketch of the ore deposits in the beds below the Carboniferous.

Archæan.

The base of the Archæan system, according to Pumpelly, is the Laurentian, to which succeeds the Huronian, the latter being covered in places by an eruptive series.

In the States of New York and New Jersey, the Laurentian rocks have yielded a large amount of iron-ore. Magnetites occur in the gneiss and limestones of that series, much twisted and tilted at high angles. It should be noted that these

gneisses, especially in New Jersey, are rarely free from magnetite, and are often sufficiently impregnated with it to form beds of lean ore, and in places workable deposits. Magnetite ore bodies also occur occasionally in the crystalline limestone. In many of the mines there is no sharp demarcation between the ore and the wall-rock, the ore and the gneiss both carrying the same minerals in inverse proportions.

The so-called Huronians are, however, the most ferriferous rocks in North America. In the Lake Superior region the ores are entirely derived from them. These beds are represented as resting, almost conformably, on Laurentian gneiss. (Fig. 5.)

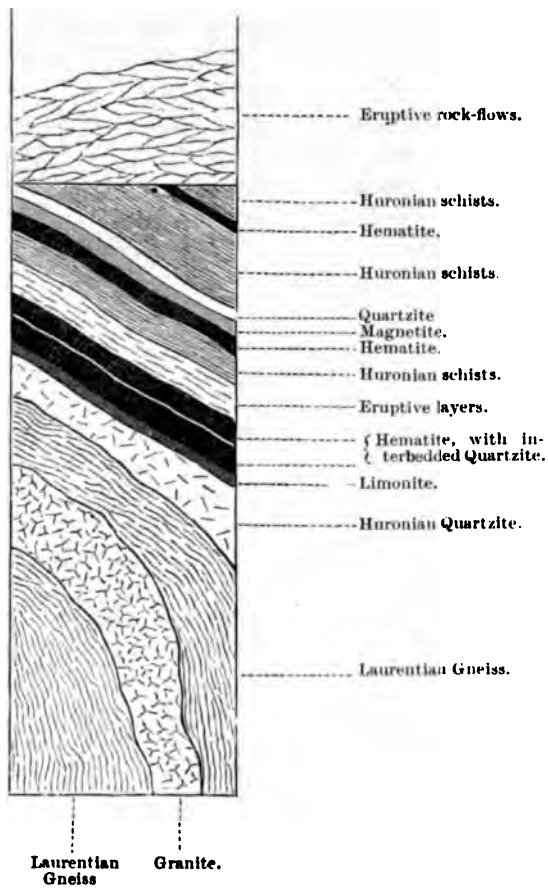


FIG. 5. Generalized Section of the Michigan Iron-Ore (after Pumpelly).

Pumpelly gives a very generalized section, representing a sequence, which in most regions is much complicated by folding and fracture. A bed of quartzite resting on the Laurentians is succeeded by a bed of limonite, the upper portion of which is hematite with intercalated quartzite. Then ensues an eruptive bedded mass, above which occur the richer portions of the deposit, good hematites with some magnetite in association with certain peculiar Huronian schists and jaspers, etc. This represents the more complex phase of the iron country: in other parts the sequence is more simple. What I particularly wish to point out is the association of these ores with quartzite, schist and jaspers, since it will be necessary to return to this subject when dealing with the views of the late R. D. Irving on this remarkable district.

In Minnesota the iron-ore consists of enormous bodies of hematite in connection with Huronian schists and quartzite, the whole being overlain, as in Michigan, by lavas of the uppermost Archæan. These are not worked at present.

In Missouri the three remarkable masses known as Iron Mountain, Pilot Knob, and Shepherd Mountain are referred to the Huronian. No beds of Laurentian age are found here. Pumpelly observes that the Missouri ores are associated with porphyries and conglomerates which are supposed to be of Huronian age. The ores are represented as being chiefly hematites. Magnetic ores and martite occur in porphyry in a true vein at Shepherd Mountain with 65 per cent. of iron and scarcely any phosphorus. These ores also occur in an immense irregular vein or mass, in places 60ft. thick, in decomposed porphyry at Iron Mountain, where the great ore body sends out into the porphyry countless anastomosing veins of ore, abounding in crystals of apatite, so as to form a reticulated mass of ore and rock. Through the atmospheric removal of the decomposed porphyry the heavy and indestructible ore-veins have been left to form an accumulating mantle of ore-detritus. The ore has lost nearly all its phosphorus through the weathering of the apatite crystals. Pilot Knob is similar. These ores are free from manganese.

Silurian Ores.

The next great ferriferous horizon in the United States occurs in the Trenton and Canadian groups of the Lower Silurian. In the Appalachian region from Vermont to Alabama

is a limonite-bearing belt associated with limestones and schists of this age. Numerous hypotheses, says Pumpelly, have been advanced to explain the origin of these limonites. Dana thought they resulted from the leaching of beds either of iron carbonates, or of a limestone carrying iron carbonates. Somewhere I remember having seen the suggestion that these limonites had resulted from the oxidation of immense beds of pyrites. However, we have very little time left to investigate their origin. The most interesting fact to note is—that the Alleghany Mountains contain such important ferruginous horizons in ranges which constitute a sort of framework to the great interior Coal-basin.

There is yet another horizon, in the Upper Silurian of the Alleghanies, where hematiteores of Clinton age are known as "fossil" or "dyestone" ores. These have the following features in common:—(1) Association with olive shales which owe their green colour to ferrous silicates; (2) The occurrence of the ore only above drainage level, changing from ore to ferruginous limestone below that level.

The Views of R. D. Irving.

Sufficient has now been said with respect to the principal horizons for iron-ore in the United States. A short notice of Mr. Irving's views as to the origin of the iron-ores of the Lake Superior region must conclude this brief reference to trans-Atlantic deposits. Recalling the generalized diagram of the sequence before folding took place in that region (Fig. 5), we must also remember the amount of siliceous matter associated with these ores. Two distinct theories have been brought forward, one implying a sedimentary, the other an eruptive or volcanic origin. Owing to the amount of bedded igneous rock between the two series, and also to the fact that in some districts the Huronian beds are succeeded by great sheets of Archæan lavas, the latter theory has been held by many.

Mr. Irving criticizes the several points of the igneous theory, referring especially to the views of Mr. Wadsworth. He observes that the occurrence of fragments of banded jasper in the overlying quartzite indicates that these substances had reached their present condition at an early date.

He first studied the formation in an unfolded district, and became convinced that not only the banded-jasper schists, but several other forms of ferruginous rocks, such as magnetite and

hematite schists, etc., must and have had a common origin with the ordinary ore and jasper. This was in 1883, after which year he undertook much microscopic work in this connection. The silica which is so abundant in the ferruginous schists presents every evidence of chemical origin; fragmental quartz being seen, but always sharply distinguishable from the water-deposited silica.

Rejecting the metamorphic as well as the igneous theory, Irving refers to the fact that the least altered forms of ferruginous schists contain a considerable portion of some carbonate. This favours the notion of the replacement of a rock originally dolomitic or calcitic by siliceous and ferruginous substances.

In the uncontorted district certain regularly-bedded hematites could be traced directly into one of the carbonate-bearing beds, showing the gradual replacement of the rhombs by red oxide of iron. He does not appear to offer any suggestion as to the source of so much silica and iron.

His general conclusions as to these ores may be stated briefly as follows :—

(1). That the original form was a series of thinly-bedded carbonates interstratified with carbonaceous shaly layers, also often impregnated by the same carbonate. This carbonate was usually ferriferous, though probably there were intermediate forms between it and dolomite. Such a series finds parallels in the carbonates of the Coal-Measures and the so-called "black-band ores."

(2). The change was effected by a process of silicification, which varied in degree up to complete substitution.

(3). The iron thus removed at the time of silicification passed into solution in the percolating waters to be re-deposited in various places as it became oxidized, thus making the ore bodies and impregnations, and providing the colouring-matter for the jasper. Some of the hematite bands were formed by direct oxidation from iron-carbonate seams.

He quite allows that the bodies of rich ore may have had different origins, and that for some cases there is at present no satisfactory explanation. This affects both magnetite deposits and specular ore. He also thinks that some of the silicifying processes went on before the folding, but that the larger bodies of crystalline ore belong to the period of crumpling and shattering.

These views are valuable as being the conclusions of a man who spent his best days in this remarkable region, though they leave us completely in the dark as to the origin of the iron-carbonate itself. If we may judge from a recent paper, 'On the Crystalline Schists of Lake Superior,' contributed to the last session of the International Geological Congress, these views are also shared by his colleagues, who seem prepared to accept the most wholesale substitutions as secular processes taking place under ordinary conditions, and without the aid of exceptional heat or pressure.*

We must now recross the Atlantic, and since there are no Archæan iron-ores of note in our own islands, I propose to give a short account of the "Iron Mountains" in Swedish Lapland.

Gellivara, etc.

The information is derived from the official report of Torell and his associate surveyors, and was published at Stockholm in 1877. The Swedish and Norwegian Railway Company (formerly the Northern of Europe Railway Company) have constructed a line from Luleå, on the Gulf of Bothnia, to Gellivara, the distance being about 120 miles. This place was first heard of, as an iron locality, in 1704, and in 1735 a concession was granted to Lieutenant Tingwall, who ceded his rights to one Steinholtz. The first furnace was built in 1742. To cut a long story short, I may state that all attempts at profitable working failed for upwards of a century.

There is something so attractive in the idea of an "Iron Mountain" that it seems almost a pity to qualify the allusion in any way; but the prosaic Swedes tell us that the deposit of iron-ore really occupies only about $\frac{1}{10}$ of the surface of the mountain—say about 160 acres—though from the high angle at which the beds are inclined the ore, in most places, reaches too great a depth to be ever bottomed. The hill itself rises with a

* Since the reading of the paper my attention has been drawn by Prof. Rupert Jones to a recent article by Van Hise, in the 'American Journal of Science' (Vol. xxxvii, Jan., 1889), who observes that Irving's fundamental conclusions have been borne out by late investigations, viz., that the original rock of the iron-bearing formation is a cherty iron-carbonate, from which the various phases of rock and of the ore found in it have been produced by a complex series of alterations. These ores are not the results of carbonates of iron which have altered in place, but it is almost certain that such iron carbonates have been the source whence the iron oxides for these ores have been derived. The origin of this cherty iron-carbonate, Van Hise says, is one of great interest, but at present we are left in the dark upon this point. *Possibly we may* hear something further ere long.

gradual slope some 500 or 600 feet above the surrounding country. A plan with two sections showing the principal outcrop is submitted. This outcrop, according to scale, has a length of 18,000 Swedish feet—say three miles—with a mean width of about 250 feet. (Figs. 6, 7, 7a. For fig. 6 see p. 140).

FIG. 7. Nearly East and West Section at the east end of the Mountain.

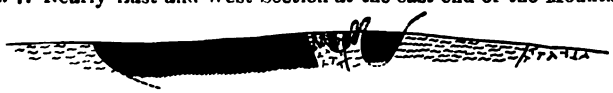


FIG. 7*a*. North and South Section (along the line A B), towards the west end of the Mountain.



The ore occurs in a gneissic series, which is compared to the so-called "red gneiss" of southern Sweden. This gneiss varies greatly within the area both in colour, texture, and mineral composition, but, taken as a whole, it is the principal constituent of Gellivara's "Iron Mountain." It frequently contains hornblende and black mica in considerable quantities, so as to assume a greyish colour. In some places it is strongly foliated, with much hornblende and iron oxide impregnated in the mass. The gneiss is also much seamed by veins of granite, the principal outcrop being close to a large mass of granite. The report expresses an opinion that this granite has uplifted the gneiss, compressed the beds and the ore, and brought the latter to day by numerous folds. It should, however, be noted that the greater part of the ore is not actually exposed on the surface, its presence where there is no uncovered knob being indicated by the compass.

The ore forms distinct and constant beds in the gneiss. In some cases the ore and rock pass into each other, so that the ore contains hornblende, felspar, and other minerals, whilst grains and even thin beds of ore appear here and there in the gneiss over considerable distances. This is exactly what occurs with respect to the magnetite ores in the Laurentian gneiss of New Jersey and New York, and there also granite is close at hand.

As a rule the ore is magnetite, with a central core of hematite in places; the latter, according to the views of Torell, being the unreduced residue of the principal ore. The ores are extremely rich, ranging up to 70 per cent. of metallic iron, the minimum analysis giving 50 per cent. Phosphorus is

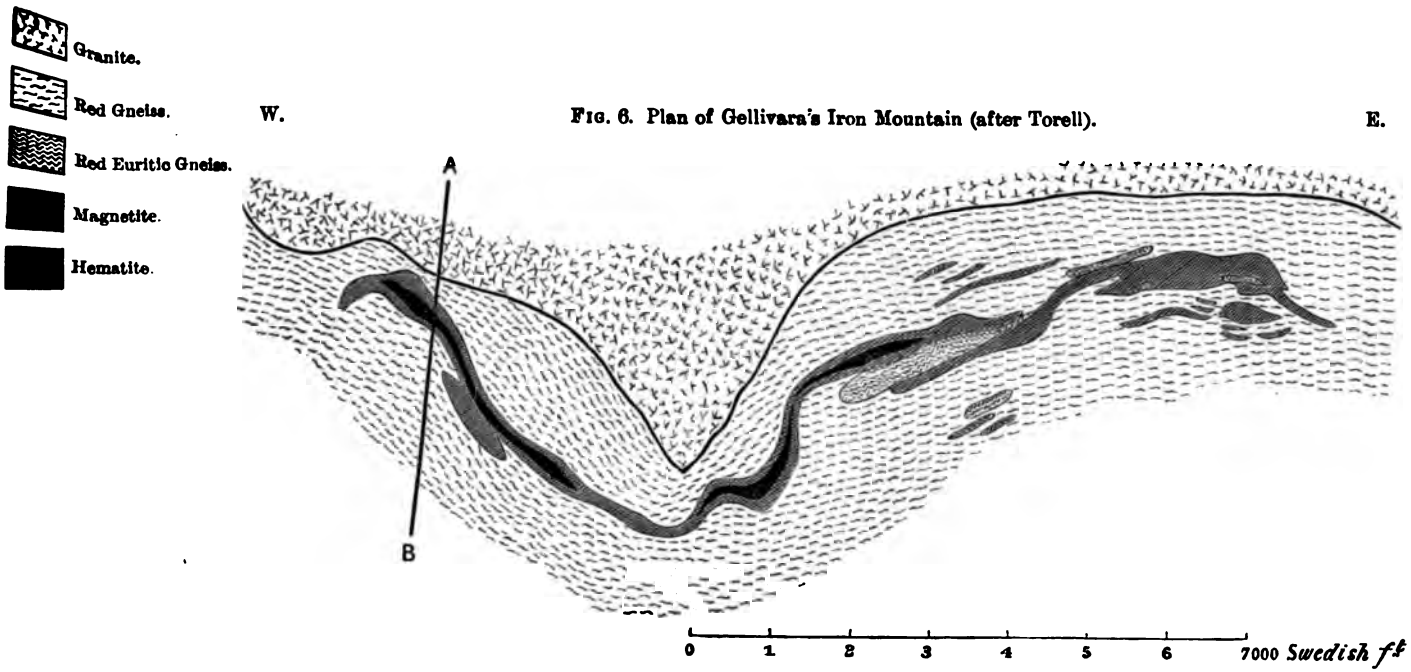


FIG. 6. Plan of Gellivara's Iron Mountain (after Torell).

abundant, crystals of apatite being numerous. There is very little sulphur or manganese, and an average of about one per cent. of titanic acid. Torell reckons only about 20 acres to contain "Bessemer metal."* If these statements are correct it is evident that the antiquity of an ore is no guarantee of its freedom from phosphorus, whilst we have seen, on the other hand, that the Bilbao ore of Upper Cretaceous age is almost free from that impurity.

Kirunavara.

One other notable development of iron-ore in Lapland may be mentioned. This is Kirunavara, or the Hill of Ptarmigans. The hill, which rises about 700 or 800 feet above Luosojaur (Salmon Lake), consists mainly of a porphyry-like petrosilex (quartz-felsite), in which a seam of magnetite occurs, extending through the hill, it is estimated, to the level of the Lake. The conditions and quality are very much the same as those of Gellivara. The surface of ore is represented as 76 acres, and the quantity above the level of the lake is estimated at 260 million tons.

General Conclusions.

It may be asked, What are the general conclusions to be drawn from the facts and interpretations which have been briefly indicated in the preceding pages. We must all admit that the origin of iron-ores in the oldest rocks is still enveloped in considerable obscurity. This is the more impressed upon us when we find that the Archæan iron-ores of Swedish Lapland are regarded as hematites which have been reduced to magnetites, whilst there seems to be a contrary impression regarding many of the Archæan ores of the United States. In fact, the presence of large masses of martite affords conclusive proof that much of the red ore results directly from the oxidation of the black ore without change of crystalline form.

Again, if there is anything to be learnt from the behaviour of iron in erupted rocks, it would seem that magnetite is the original form of iron-ore. But it may be urged that this applies only to the case of small grains, and cannot be predicated of large masses. Moreover, the presence of these same masses indicates concentration of some sort, and the

* In a letter dated 17th March last, Mr. Henry W. Trinder informs me that he has heard, on good authority, that the Gellivara ore containing so much phosphorus is the portion next the igneous rocks, "and that a few feet from such rocks the phosphorus ceases."

question really resolves itself into this—not what is the origin of the iron, but what have been the causes of its concentration.

There is a growing impression amongst geologists that many of the old gneisses are really not the result of ordinary sedimentation, but that they represent a modification of rocks having more or less of an igneous origin, the basic igneous rocks being represented by the hornblendic gneisses, and the acidic igneous rocks by silico-felspathic gneisses, etc. If this view be the correct one there can be no room for the action of decayed carbonaceous matter such as finds a place in the imagination of a certain school, founded on the presence of graphite, which may have had a very different origin. It should be mentioned in this connection that the latest views of some American geologists are to the effect that the Laurentian rocks may be newer than the beds which repose upon them, having been more or less reduced to a state of igneous fluidity or, at least, of plasticity so as to have been completely re-composed at a period subsequent to the deposition of the overlying beds.

But what has all this, you may say, to do with concentrations of iron-ore? Merely that the theory of the leaching of beds by acids of organic origin, generated in the beds themselves, can scarcely be applicable to the explanation of the masses of iron-ore in the very oldest rocks. How far acids of organic origin are accountable for the immense substitution which, according to the late R. D. Irving, has taken place in forming the Huronian iron-ores of the Lake Superior region we cannot say. In this case it would seem to have been silicic acid which helped to decompose the original iron-carbonate, but as to the origin of such an ancient iron-carbonate or the sources of so much silicic acid we obtain no information.

But whatever may have been the principal causes of concentration in the older rocks, which were probably formed under physical conditions as regards atmosphere, very different to those which afterwards obtained, there seems to be little doubt that from Carboniferous times down to the present day we owe most of our accumulations of iron-ore, whether of original deposition or of substitution, to the leaching of beds by acids, which were in the main the result of the decomposition of organic matter, chiefly of vegetable origin. Reduced and dissolved by carbon-products, iron moves about in all directions; its solutions permeate the rocks and impregnate many a

spring. Sometimes it collects into lumps and concretions, which obey the laws of segregation like any other crystallizable matter in solution: sometimes it takes the place of limestones more or less completely, and tarries for a while as carbonate in a series of massive beds. Then comes the rival element in oxygenating waters, whose entry is facilitated by fissures, shrinkage, denudation, and all the conditions which favour percolation. The resulting oxides are more or less fixed bodies, stones, in fact, of an indestructible character, which often constitute some of the most enduring elements of the rocks in which they are enclosed.

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EXPLANATION OF PLATE II.

(*Rock-sections enlarged by a two-inch objective.*)

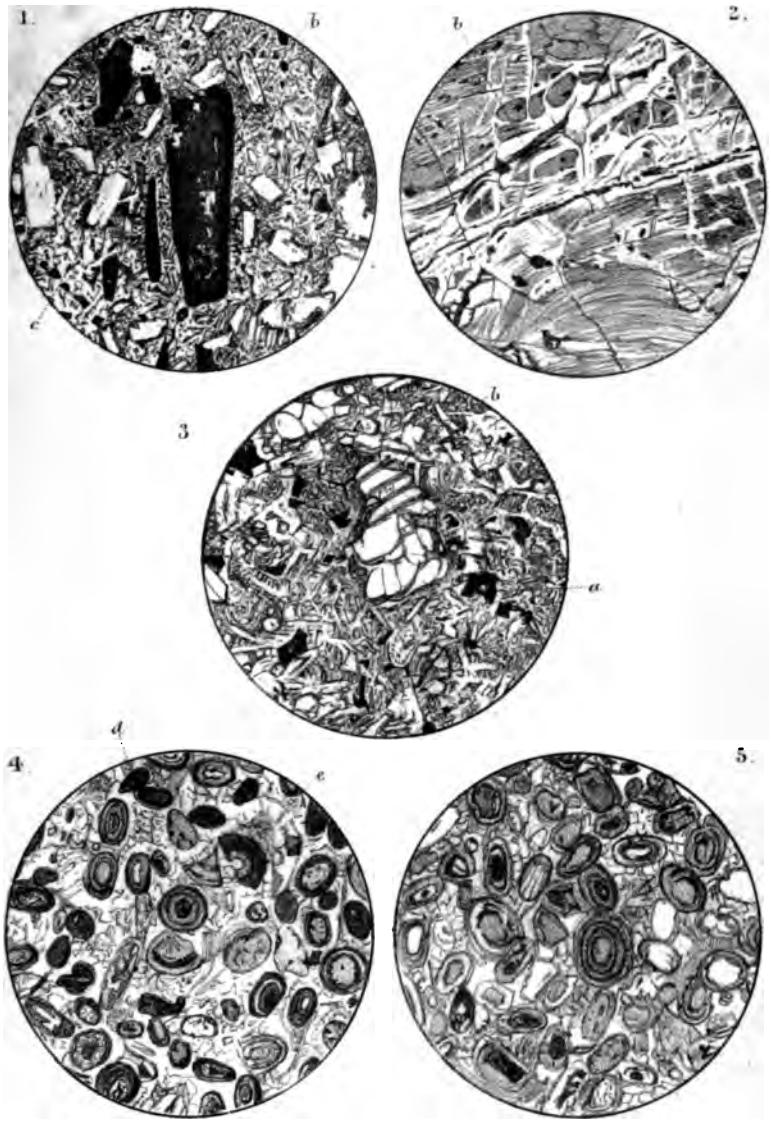
FIG. 1.—*Hornblende-andesite* from America. *b*. Crystal of hornblende passing on the exterior into secondary magnetite. Some of the smaller crystals of hornblende have already passed into magnetite. *c*. Crystal of andesine.

FIG. 2.—*Black Serpentine* from Cadgwith. The process of conversion from olivine to serpentine is accompanied by the separation of magnetite dust (secondary magnetite), *b*, beginning in the centre of the fissures.

FIG. 3.—*Olivine Basalt* from the Drift of Finchley. *a*. Crystal of primary (idiomorphic) magnetite. *b*. Magnetite dust in the fissures of the olivine.

FIG. 4.—*Magnetic Iron-ore* from Rosedale. The ground-mass consists mainly of carbonate of iron, slightly argillaceous. The magnetite resides in the concentric bands of the spherules, especially towards the exterior, Percentage of metallic iron about 48.

FIG. 5.—Oolitic portion of *argillaceous carbonate of iron* from the Cleveland main-seam at Guisborough.



IRON MINERALS AND ORES

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A Visit to the Volcanoes of Italy.

By Prof. J. F. Blake, M.A., F.G.S.

(*Read April 5th, 1889.*)

It is not to be supposed that a stray geologist devoting a month to an excursion over so wide an area as that covered by the volcanoes of Italy should be able to add much, if anything, to our stock of knowledge about them. Yet to himself there is all the difference between a personal knowledge and that which may be acquired from books. For my own part my knowledge of volcanic phenomena was confined to their description by others, and the observation of those that had long been extinct, either in this country, the Auvergne or the Eifel, and I found on personal acquaintance that there were many things in active volcanoes that I had not at all understood.

I will first describe what I learnt at Naples.

On nearing Naples by the train you enter, of course, on the east, and leaving Somma on the left pass under the slopes of Vesuvius, the thin floating cloud on which, not larger than the cloud-banner on ordinary mountains, but constant in all weathers, is the only indication that it is in an active condition. Only once, on a clear evening, while clouds were hanging over it in the sky, did I see a gleam of redness on the summit, like the reflection of a pottery furnace, but more fitful and changing. Its flanks are clothed with vineyards and gardens, amongst which are innumerable houses. At a distance the lava-streams make little show, as there is not much to distinguish them in appearance from the ordinary ground. A somewhat darker tint enables a more experienced eye to follow them on the slopes. The bulk of the mountain is composed of ashes and scoriæ, which is easily worked, yields two or three crops a year, and soon gets worn into deep furrows, so that the roads in general lie below the general surface of the ground.

I think my first disillusion was as to the bulk of lava in an average volcano. I had supposed that the greater part was lava, and that the fragmentary portions were comparable in bulk to what one finds them to be in the more ancient volcanoes in this country. But though the lavas of Vesuvius may form, as it were, the ground-work

which supports the ashes, and though without them the denudation of the mountain would be much more rapid than it is; yet, for all the show they make on the surface, they might be taken away without in any very serious degree altering the bulk of the mountain.

My next disillusion was as to the appearance of a lava-stream. I was prepared to see it scoriaceous and rough, but expected that on the surface it would have a somewhat glassy appearance, like that of the slag of an iron-furnace, or be black and rocky, like the old lava-streams of the Auvergne. Such lavas, indeed, one may find, as will be presently described, on the higher parts of the mountain; but one's first acquaintance is made with those that have flowed farthest, and these present a very different appearance to what I had anticipated. I can compare them to nothing better than to heaps of London road mud, tossed by carts in some waste place, and dried. There is the same rough and muddy appearance, the same heaping up here and depression there, the same spotty surface. The reason of this is that one does not see the rock at all. It is all clothed over with a peculiar lichen, which fixes itself on each new flow till it has exhausted the ingredients it requires for its growth. Flows of this sort occupy all the lower slopes of the hill and run into the ancient valleys. A very instructive section of such a flow is seen in the Rione la Novella, where the lava of 1855 is quarried for the streets of Naples. Here the whole surface is covered for two or three feet with a scoriaceous scum of this sort, and beneath it lies the solid lava, resting on a narrow base of scoriæ, which acted as a kind of damper between the molten rock and the soil of the valley, which is only altered by being burnt and reddened for a foot or so on either side. This section shows well why the real lava shows so little on the surface.

Though all proceeding from the same mountain, each lava has its own special petrological characters, which renders it more or less useful for industrial purposes. The lavas of 1855 and 1767 are the principal ones quarried, partly, no doubt, from their proximity to the city. The former is very liable to spheroidal weathering, so that the roundish blocks which are used in the streets are generally cracked towards their margin in lines which run more or less parallel to the circumference. Dr. Lavis pointed out to me that the blocks of lava with which they paved the streets of the ancient Pompeii have a similar character, the cracks being well developed wherever the blocks are exposed.

Another rather important illusion dispelled is concerning volcanic bombs. I had thought from what I read in text-books that these were masses of lava tossed out of a crater, whose gases expanded as the mass rose and made its interior full of cavities, while its rotation in mid-air made it spherical, and its rapid cooling made its exterior solid or glassy. But are there any such bombs? I was certainly, at a later date, shown one on Volcano which was supposed to have this origin, being an ejected block, remote from any lava-stream, vesicular within and glassy without and tolerably round, but even this needs no such explanation as above. It is far more probably an old piece of scoriaceous lava which fell into the throat of the crater, got rounded by melting, had its surface vitrified, and was then ejected as any other block might be. However, be this as it may, whether there are any such bombs in existence or not, I saw none anywhere on Vesuvius, and Dr. Lavis tells me that there are none to be found. Yet I saw thousands of rounded masses of lava, solid without and scoriaceous within, having, in fact, all the characters of the so-called bombs. But in the quarry above referred to we see the lava in section. It has not long been exposed to the action of the weather, and we see how it is composed. Now the upper scoriaceous part is full of these rounded masses of all sizes—in fact, more than half-composed of them. At the top they are loose, having been disintegrated by the weather, but at the base, nearer the solid lava, they stick together by their surfaces and have to be broken away. Yet, though they are so abundant here in their natural place, not a single one is anywhere to be found on the adjacent fields. The same phenomenon was pointed out to me by Dr. Lavis all over the mountain. When once the surface of a lava-flow was made out, there we found plenty of rounded masses, but they stopped dead at the edge of the lava. Not a single one occurred anywhere else. Moreover, if the lava has any particular character these masses correspond to it. The more solid parts of those in the quarry were just like the lava below.

Under these circumstances there seems to me no escape from Dr. Lavis's conclusion that these masses have never left their native stream; they have never been in the air at all, but must have been generated by the stream itself. Dr. Lavis's explanation is a very simple and natural one, if I understand it rightly. Everyone admits that the lava-stream does not flow evenly, but that the top rolls

over and becomes the bottom. In this process the scoriaceous surface gets broken up, and the fragments get imbedded in the softer parts of the lava, near the base. Hence, from the presence of gas-cavities, they are always tending to rise; and, as the lava flows on, they do rise, as stones do in a glacier, and ultimately reach the surface, rounded and smeared over with solid lava. With this collapse of the volcanic bombs we may ask ourselves—Is it reasonable to expect such things? A volcano which throws out such masses broadcast would be in the explosive type of eruption, while the lava belongs to the effusive type. We know these two types of eruption may occur simultaneously, but is it to be expected that they should also occur at the same spot, in the same crater? I think not.

In connection with this may be mentioned another correction of a former idea. I had always conceived lava and ashes as distinct things—that you could always say this is a flow of lava and that is a bed of ashes—but here I found them very much mixed, and in other places the distinction became almost hopeless. The mountain sides of Ischia, for instance, are mostly of the ashy type, but this shades off imperceptibly into solid lava-rock. I need not, perhaps, stay to explain how this is brought about—it is easy to conceive.

The last of my initial illusions on which I received a sudden enlightenment was on the subject of Vesuvian minerals. I had once possessed a collection of these, and was astonished at their number, so far exceeding what we can meet with in the ashes or lavas of the old volcanoes, and hence I conceived that Vesuvius from a mineralogical point of view must be quite an exceptional volcano; but I soon discovered that properly speaking these are not Vesuvian minerals at all, and that, in fact, it is not a prolific mountain. It is not even easy to pick up a handful of leucite crystals, as it is on some other Italian volcanoes now apparently extinct. All the so-called Vesuvian minerals are found, with few exceptions, such as augite, in the ejected blocks of Monte Somma. In the great eruptions of antiquity, which burst up through the stratified rocks and formed the original great crater-ring of Somma, there were thrown up huge masses of these rocks, reacted on by the gas and molten matter, by which these various minerals had been formed in them in the bowels of the earth. But since that time, now that a good passage has been formed in the centre, no

more appear, and only fresh examples of the old ones are newly exposed by denudation.

Such are the general lessons to be learnt on the lower flanks of Vesuvius, but there are two other special spots on which a word must be said, *i.e.*, Herculaneum and Pompeii. As to the first, it is very disappointing. To see it you take the train to Portici, the Portico, that is, of the King's Palace. Here down a dirty street you find a door, like the door of some public bath. Candles are lit, and you descend the stairs as though about to visit the Thames Subway without gas. After groping along for some way the guide informs you that this is the wall of the theatre on your left. At last, on your right, you find a gap, and, passing through it, emerge into a small excavated amphitheatre with rising seats of stone, most of which are covered with volcanic mud, which still fills many of the passages. So along dark subways you come here upon a statue and there upon a wall, with carving and façades at intervals. Such is the underground theatre, which is all that has here been worked out.

I suppose it is generally known to geologists that Herculaneum was not overwhelmed with lava, but with a flow of mud, which travelled further than a molten rock, and buried without burning the ancient town. The liquid mud has considerably solidified, so that the ruins are hard to extricate, and the newer houses above them find a solid foundation. The site of the old town was quite obliterated, and after vineyards had grown above it a new town appeared, and finally a palace. It was in sinking a well to supply this palace with water that the theatre was discovered, its lava-built walls being harder than the surrounding tuff. There is, however, another portion of the old town not far off which has been entirely cleared, and now stands within walls, but does not occupy much more than an acre or two. In this we find a handsome promenade with Doric pillars, rows of shops and dwellings of taste, with painted and decorated walls. The most interesting portion is, perhaps, the wine-shops, with their huge wine-jars built into the counters. Many of these had fastenings of lead, none of which had been melted, proving the absence of heat in the material which had enveloped them.

Herculaneum is altogether outdone in interest by Pompeii, which lies further to the south, some ten miles from Naples. This was built on an exceptionally good situation, on an elevated plateau

overlooking the sea, and with a long plain stretching between it and Vesuvius, which is some seven miles distant. It would seem almost impossible that this should be overwhelmed. Had any stream of lava, or even of volcanic mud, flowed from the mountain it would have been separated by this plateau, and have passed on either side, leaving the city untouched. But the destruction came from above. An immense quantity of light, pumiceous dust, like that which in 1883 was ejected from Krakatoa, was carried by a wind setting in that direction till it settled on plateau and on plain alike, and gently buried the city beneath the load. It is for this reason that the city is so well preserved, and so many relics have been recovered uninjured. Some of these are preserved in the Museum erected on the spot, but the most important have been removed to the National Museum at Naples. Amongst these relics perhaps the most interesting are the loaves of bread of the modern cottage-loaf shape, now charred and blackened without heat by the natural decay of volatizable material, little more than the carbon being left. Next to these is the suffocated dog, petrified in the midst of its death-contortions, and the pair of children dying in each other's arms. At Naples the richness of the relics is the principal feature. Here are gems of intrinsic worth—emeralds, rubies, sapphires, pearls, beautifully carved and artistically set in gold, intaglio seals, marble sculptures, ornaments, household utensils, and ladies' knick-knacks, large campanel bells, arm-chairs, bedsteads, stoves, doors, and door-knockers, all so beautifully preserved and handsome in themselves that one may fancy one is wandering amongst the art-collections of South Kensington, and can scarcely believe they have been buried for 1,800 years. It serves to show how little change may take place in superficial deposits, even when these are porous.

This is not the occasion to say anything of the antiquities of the city, were I capable of doing it; but even a geologist may take part in the admiration of this, which is practically a fossil city, and wonder at its perfect preservation. The streets seem to have been deserted but yesterday. The causeways at the sides are polished by the feet of the ancient Romans, and the narrow roads between, paved with huge blocks of lava, and crossed here and there by stepping-stones, are worn by the wheels of their carts or chariots. The houses are practically untouched, the walls undecayed, but the secrets are all exposed, and the privacy departed. There are no alleys or slums

in Pompeii; for except for the streets, the whole area is contained within the walls of the several houses. To a geologist as such —though the most enthusiastic here forgets his special science, and revels in the marvels of the place as an antiquity—the most interesting features are the wharves, to which the merchandise was brought. These are now a long way from the sea, and though not much above its level, add one more to the many proofs hereabouts of the changes in the land since the epoch of the life of the city, and the filling up of the sea by the eruptions of the time. Standing in the streets of Pompeii, Vesuvius seems a long way off —some seven miles—and, with the wide plain stretching between, one learns to appreciate the force with which light pumice may be ejected from a comparatively insignificant centre.

So much for the lower slopes of the volcano, and now for the mountain itself. The two parts of which it consists—Monte Somma and Vesuvius—are very different in their characters; the one is the old, the other the new. The slopes of Monte Somma extend to an almost interminable distance, and are scored by deep ravines, some formed by the coursing streams, and some by the peasants' pathways on the intervening crests; but all are deeply clothed with underwood and herbage to the very summit of the mountain, and afford, in the spring-time at least, a great temptation to the geologist to transfer his attentions to the botany of the region. There is not very much to learn on these slopes and ravines, except that the lavas are markedly leucitic, which is not the case with those of Vesuvius. Otherwise the whole mass is of loose volcanic dust, etc., and no good section is seen in most of the valleys till one reaches the summit, and looks over the edge at the inner crater wall.

In contrast to this, Vesuvius itself is a scene of utter desolation. Some isolated patches which have escaped the ravages of later eruptions, such as the tongue on which the observatory stands, have trees and shrubs and herbs; but above a certain level not a blade of grass or other vegetable product breaks the monotony, but all is a wild mass of lava and ashes. It is in these higher parts that are found the most frequent examples of that ropy form of lava, so generally distinguished from the scoriaceous form, and interpreted as being the result of a greater viscidity. Certainly the greater abundance of the ropy lavas near the summit would indicate that they had moved

slowly in comparison with their rate of cooling, and had not, therefore, travelled a great distance before they were stopped by their consolidation.

It is weary work going up Vesuvius, on the Pompeiian side at least. The lower slopes are well enough, as a pathway is worn on the ashes, and the lavas that have to be crossed are pretty firm; but higher up the lavas become slippery, and when they are not rope-like, which is by no means their constant character, they are smooth and sloping, and afford a somewhat uncertain foothold, or else they are thrown up into suddenly petrified snake-like forms. On this southern side are some excellent examples of lavas on rapid slopes, consolidated before they could reach the more level ground. Some of these are of recent origin, and are not yet entirely cool. But the most interesting feature is that of the lava-tunnels. Here is seen a more than usually cylindrical surface, and on some part of it is found a gaping hole, into which when you look, you see a hollow tunnel extending either way beneath the lava crust. This has been formed by the outside hardening, while the more liquid interior was still capable of motion. But in this case, instead of the upper surface being carried along on the top of the stream, and rolling over at the end, it has clung to the sides of the ground over which the lava is coursing, and so the molten part has forced its way out at the end, and when the supply ceased it has left a hollow whence it flowed, and the unsupported archway, falling in here and there, reveals the tunnel to the observer. One's natural desire is to creep into this tunnel, and trace the origin of the lava, but the objection to this is that if you could get there the lava would be hot; and, in fact, though the arch is cold, and has been formed many months, the tunnel is still occupied by hot acid vapours, which course along it, and from a distance may be seen to rise through the holes on the surface. Indeed, you cannot treat the hollows on a volcano in exactly the same way as you would a sea-worn cave.

You are now on the final plateau—or, as they call it, "piano"—from which the topmost cone ascends, and the stiffest bit of the climb is before you. There is a long sloping talus of loose ashes and scoriæ, lying at their angle of rest, which looks very tempting, but it is hopeless to ascend this

way. Each upward step brings down on you an avalanche of the higher *débris*, burying your feet and legs, driving you down again, and teaching you that in bulk they are not quite cool. The only way is to take to the rough and horrid lava-stream, and, clambering from point to point as best you may, you at last stand on the level summit—a large filled-up crater of the eruption of 1872, the low crater walls, broken down in many places, surrounding you on every side. And now you are in the presence of the actual volcanic activity. The whole ground is pouring out the fumes of hydrochloric acid from a thousand vents. The soil is composed of the decayed rocky material, now disintegrated into a yellow dust, impregnated with the acid, and hot to hold. Amongst this dust lie abundant loose crystals of augite, which the acid seems unable to touch, and which are therefore loosened from their surroundings. The presence of these hot acid vapours—different volcanoes having different acids—seems to indicate that the agency at work is not merely heat, but includes also chemical reactions. Scattered all over this surface are very peculiar masses of various sizes, which are lava-cakes, the miniature representatives of the supposed volcanic bombs. They are rather flattened in shape, blistered and scraggy in outline, dark and shining on their surface, and torn into shreds by the escaping gases. They have cooled suddenly in the air, and fall all around the vent. There must be some danger in this spot, as an explosion slightly more violent than usual might bring a shower of them down on one's head. The actual spot from whence these are now ejected is a smaller cone built up of them, and rising in the centre of this acid-fuming plateau—itself, as before mentioned, the interior of a larger crater. You climb the sides of this smaller cone and look down from the windward side into the roaring abyss, filled with dense clouds of steam, which rise to the crater's edge, and are then borne away by the breeze. The roaring proceeds from a boiling mass of lava at one side, which is always working and densely fuming, but ever and anon throws up a cloud of cakes, which fall, for the most part, whence they came, but may at any time fall beyond the crater's edge. Such of them as fall within the crater, on the sloping bank which leads down to the cauldron, are seen to fall red hot, and one who can stand the acid fumes may run down

rapidly between the outbursts and fetch one up, having first, with a stick, rammed a coin into it while molten. Such a cake brought by a guide for me while watching at the crater's edge was too hot for me to hold when brought, and burnt the paper in which I ultimately wrapped it. This is all, however, that I saw of molten lava, either here or anywhere else. The whole crater is too filled with steam to be uncovered except very occasionally. Dr. Lavis in his numerous ascents had seen it once or twice, but I was not so favoured on my solitary visit. The road down lies on the surface of the finest dust, lying at a high angle, into which the feet sink at every step, but down which you are rapidly pushed by the descending dust above you. It is up this cone of ashes that the railway is carried, starting from a mass of solid lava below and landing on the edge of the larger crater.

The ascent of Vesuvius is sufficiently interesting and exciting, especially the action of the crater itself and the acid plane around it, but, with these exceptions, I was rather disappointed in the mountain. It seemed to me a dirty heap of rubbish with nothing majestic about it, and the rocks are without definite character. We see lava and ashes, but we cannot get much further into details. They are not trachytes, and they are not dolerites, but a sort of intermediate variety, probably, from their general dark colour and the presence of crystals of augite, more basic than acid. They may perchance be more interesting microscopically, but I have not as yet had time to examine them in that way. The older eruptions, including the products of Somma, are more characteristic. Here, at least, are leucitic lavas, and pumice is abundant in the tuffs, without, however, any concomitant obsidian.

Viewed as a whole, I regard the volcanic mass, as well as the Phlegræan fields to be presently described, as originally a submarine eruption. All down the long neck of Italy till the railway branches off west to Naples a long line of limestone hills is followed, which seem to have suffered no disturbance from the nearness of the volcanic centre. South of the junction they turn suddenly to the west, and the railway again hugs their base, till nearing Naples they recede further south and form an amphitheatre round Somma, and jut out into the sea at Sorrento and form the island of Capri, with its nearly horizontal strata. This forms the true sea-margin, within the corner of

which Vesuvius stands. No stratified rocks are seen at its base; but the volcanic products descend into the sea. Thus the volcano must have started below the sea-level, and its real elevation is greater than it seems. This may in part account for the lesser height compared with Etna, which everywhere rests upon stratified rocks, which are, nevertheless, largely concealed by the ejecta of the mountain. It may also account for the hydrochloric acid; but not, perhaps, entirely, as no hydrochloric acid is found in the Phlegræan fields, which equally rise from a submarine basis.

To these fields we must now turn. Naples is well separated from Vesuvius by a deep bay of the sea, and this is continued inland by a wide plain, which belongs neither to the north nor the south. On the north side of this plain the ground gradually rises on all sides—from the south, the east, and the north, and if we count the islands and promontories, from the west side also. Into the flanks of this conical mass is worn the irregular bay on which Naples is built, with the sloping beds of tuff forming a rising background. Taking the steam tram from Naples to Puzzuoli the road rises rapidly within the limits of the city to Posilippo until a tunnel is reached, which pierces the highest crest, and in which the light tufaceous rock is as horizontal as such irregular deposits can be. Once pass this tunnel and you find yourself in a new and isolated country, with numerous distinct elevations, each of volcanic form. On mounting one of the higher of these—I selected Monte Barbaro—and looking round, one finds one's self in the midst of a vast theatre. All around stretches a more or less precipitous cliff, irregular in its outline, but always steep within and sloping away gradually without. The conclusions cannot be resisted that the whole area consists of one huge volcanic pile, comparable in size to the Vesuvian, but lower in elevation; that the whole of the Phlegræan fields lie within its eviscerated crater; and that the minor volcanic cones are so many parasitic products rising from the crater floor. Far away to the south lies the Vesuvian mass, and further to the north the great extinct volcano of Rocca Monfina, forming a triangle of vents. The whole area would thus correspond somewhat to the Crater Lake of Bracciano. If such be the true character of the Phlegræan fields the whole number of the small cones belong to one group,

and are likely to have a common character. This is certainly the case; for they are all of the acid type. There is even less lava to be found here than in Vesuvius, and what there is occurs in long sheets of trachyte, which are more or less porphyritic. One of these is well seen on the road to Puzzuoli, another forms the slopes of Monte Barbaro, and a third forms the piperno worked near Astroni. But the tuffs are also light in colour, and are derived, therefore, from acid rocks. There are, of course, small exceptions, but whether seen in the cliffs above Naples, in the tunnel of Posilippo, in the slopes of the Solfatara, or around the crater of Monte Barbaro, or Astroni, they are of a dull yellow tint, fine in grain, sometimes stratified, but more often not. The darkest in tint are those of Monte Nuovo, amongst the *débris* of which there is also much pumice. The numerous craters which crowd the ground are well seen from the summit of Monte Barbaro. Monte Nuovo, being the most recent, is the most perfect, the crater-bottom being now a vineyard and the outer slopes tree-covered. In this I found an interesting proof of the heat of the eruption in the carbonized rhizome of a fern. Lake Avernus, at its side, has its base at a lower level, and its crater is thus filled with water, and a still lower outburst is seen to the north-west, into which the sea has encroached.

Of all the craters, of which there are many more, perhaps the most interesting is the Solfatara, as it is still in a heated state. Its crater walls are much broken down, and the floor is a very wide one, used partly in cultivation and partly as a collecting ground for aluminous salts. But all around the sloping crater-sides are hot, and hot sulphurous vapour is emitted from every crack. On the east side are numerous caves, whence issue sulphurous vapours clothing the sides with an efflorescence of sulphur; but the principal fumarole is at the south-east corner. It is below the level of the ground, and a dense cloud is constantly issuing from it with a roaring sound. The shallow cave, about 4ft. high, passes horizontally about 6ft., and by crawling on hands and knees the end may be seen out of which the jet is rushing; but to lift the head is impossible. The hot rushing stream occupies the upper half, and is altogether unbearable, being at a heat of 125° as it issues. The coating of sulphur and white aluminous needles is magnificent. The base of the crater is obviously only a crust over a cavity which may at any

time fall in, as it sounds hollow wherever you tread. It may be noted, however, that a stranger runs into more danger outside than inside the crater, for the way to it leads by narrow paths between steeply sloping hills, which are cultivated as vineyards, and the natives have an evil method of welcome by heaving half a brick of tuff from the slopes above, and sometimes the cannonade does not fall very far short of its mark.

It seems probable that the great Phlegræan mass may also arise from some depth in the sea, as there are no more ancient stratified rocks beneath it, and hence it may in reality be of considerable height from its base, though not now very far removed from the sea-level. It is not necessary, however, to suppose that the whole area within the outer ring was ever a single crater; indeed, it is probably not so; but from a date far anterior to any of the existing craters this area has been a centre of eruption—a sort of sieve-like spot somewhat comparable to the "rose" of a garden syringe. Of all the material that was ejected from the several pipes, that which fell beyond the present ring accumulated undisturbed till it built up the surrounding slopes. That which fell within was blown away again and again till it was carried out of the way, and the final explosions of the series, dying down to less power, have left us the little craters now visible. If this be a true account of the locality, we shall have little difficulty in accounting for the unsteadiness of the ground. With the exception of the slight change of level round the Torre del Greco, in the neighbourhood of Pompeii, all the evidences of oscillation recorded in this district lie within this area, that is around the Bay of Baiæ. Of all areas in the world the centre or floor of a great volcanic crater must be the most unsteady; though the fact of its unsteadiness does not really bring us any nearer to the explanation of the rise of the stratified rocks, of which, as regards those of the district, we have no evidence in historical times, and can only assert that they have risen since the first appearance of members of the present Mediterranean fauna. But in the Bay of Baiæ the evidence of unsteadiness is overwhelming. The bulk of Puzzuoli is built upon rising ground; but as you approach from Naples a curious sight is seen. Standing in the sea is a restaurant, the entrance to which is on the first floor, while the basement is under water. We may be sure it was not built thus;

but that the land on which it was erected has sunk into the sea. In the inner bay we find the celebrated temple of Jupiter Serapis. It is too far removed from the shore to observe, without measurement, its relative position to the sea; but on going into the enclosure we find the pillars standing in water, contained within stone tanks. These tanks are in communication with the sea, and the level of the water in them—that is of the sea—is a few inches only below the edge. Yet if we measure the depth of the tank we find it 3ft. 6in. before we reach the bottom. Hence we may conclude that they are even now at that depth at least below their original level. That they have been still lower, and have risen again is proved, as all the world knows, by the *Pholas* and other borings which have eroded the columns from a height of about 3½ft. to a height of 8ft. above the present sea-level. They have, therefore, been buried in sea mud up to 3½ft., in water whose depth was at least 4½ft. more. That they have been down is an evidence of depression of their foundation; that they are now up again, but not to the former level, is evidence of its partial re-elevation. The other evidences of change in the district are all of elevation. The bay north of Puzzuoli is surrounded by a low flat plane, on which are built the armament works of Messrs. Armstrong, and this is backed all round by a rather lofty and nearly vertical cliff. Crossing the orange and lemon groves, which flourish in the fertile soil under this protection, we can find at some 30ft. above sea-level a thickish band of sea-sand in the midst of soft stratified material, crowded with the modern shells and echinoderms of the neighbouring sea, and in no way differing from those buried to-day in the sand at a lower depth. This is our first proof; another at first sight is not so obvious. Climbing up Monte Barbaro we find it composed of a very perfect crater—almost circular—steep within and sloping gradually without, except on one side. On this side there is a narrow ridge, scarce wide enough to walk on with safety, composed of hard trachyte. On the outer side of this ridge we have what appears at first sight to be another crater, so steep are the sides and so bay-like is the outline; but two such craters close together are impossible, and, moreover, the slopes of the beds, whether trachytes or trachyte-tuffs, are *across* this outer hollow, radiating from the perfect ring. This bay is, therefore, a sea-worn bay, executed since the elevation of Monte Barbaro.

The only other spot I visited in this neighbourhood was the Island of Ischia, rendered memorable by the earthquakes of 1883 and 1885, which destroyed its principal towns. This island is pleasantly reached by a daily steamer. With the exception of the Ponza Islands it is the most remote within the range of local steamers, and is the largest of the islands. It is so compact in itself and so complex in its formation that though of a similar type to the Phlegræan outburst, it must, I think, be considered as an entirely independent volcano. For, in fact, it is not only volcanic, but a real volcano. This is well shown in Professor Judd's plan of the island in his book on volcanoes, in which, however, the shading is unfortunately inverted so as to turn the crater the wrong way round.

The town of Ischia is at the south-east corner, on the flanks of the cone, which is more or less broken down along the east; but on reaching the site of Casamicciola a vast amphitheatre opens out in the background, with steep and almost precipitous sides. This is the huge crater-ring of which the mountain of Epomeo forms the highest peak. It is really a magnificent mass. A stiff climb through woods and vineyards, clothed in the spring-time with a lovely carpet of white and purple orchids, ablaze with the yellow broom, and green with the young maiden-hairs and trailing *Selaginella*, brings you to the summit, and the whole island lies in a picture before you. It is for the most part composed of white trachyte-tuff, with the sanidine crystals undestroyed, giving a porphyritic aspect to the whole. Slope after slope of this spreads out in lowering terraces towards the west, carved into isolated peaks, which look large at close quarters, but sink to their natural position as seen from the summit. Far grander than any in the Phlegræan fields, whiter and cleaner than Vesuvius, and less decayed than Somma, this mountain is a delightful picture of a volcanic cone on a large scale. The slopes spread out as far as the sea, and no doubt are continued beneath its level. Very little lava is anywhere to be seen, and this only on the flanks of the mountain—a very instructive phenomenon, showing that the accumulation of tuff forms an obstacle to the outburst of lava, so that lava-craters and tuff-craters seldom coincide. The absence of lava has another effect. On the western side the natural slope of the ground has directed the river-courses in nearly straight lines, and these being over soft tuff have had an enormous

denuding effect, so that we have to cross tremendous gorges, perhaps 1,000ft. in vertical depth, giving a complete section of the cone. Nowhere have I seen such gorges, except in the pictures of the Colorado district. In the lower parts of the mass, nearer the level of the sea, there are a few bands of trachyte, and one certainly at a much higher level. Of these one can be certain, but in many places it is impossible to say whether what is seen is indurated trachyte-tuff, or decayed trachyte; possibly it is both. Why should not the materials of the trachyte be so heated locally as to be recombined into a rock? Within the crater-ring, at least towards its base, there is locally observed another phenomenon, viz., the beautiful fineness of the deposit, and its stratified appearance. It is in this material that shells of the neighbouring seas have been discovered at a height of 300ft., showing that the mountain has been elevated bodily since it began to form. It may, however, like the Phlegræan fields, have gone both up and down, since there is one crater of a parasitic cone, which is now below the level of the sea, and forms the harbour of the Lago di Bagno. The principal of the parasitic cones lie in the same portion of the island, and are of great interest in themselves, so very perfect are the craters, some of which are occupied by lakes at a higher level. One of these, Monte Tabor, is a mass of pumice of a very peculiar kind, rendering it quite useless for commerce. It is full of porphyritic crystals of sanidine, like the trachytes of the district. I had never seen a porphyritic pumice before; but, though I do not find much about it in text-books, Dr. Lavis assures me it is a well-known rock. One could scarcely ask for a better proof of the preformation of the crystals which thus occur porphyritically in a matrix the very opposite of a crystalline one. I am not aware that any obsidian flow is anywhere known in Ischia, any more than on Vesuvius, or Monte Nuovo; so we must begin to emancipate our minds from the notion that there is any necessary connection between this and pumice. Nevertheless, near the harbour of Casamicciola, I found in the coarse agglomerates large masses of what I should naturally describe as a perlitic pitchstone.

But I have reserved for the last the most interesting part of Ischia—that which led me to visit the island—the crater-floor itself on which Casamicciola stood. By calling the ground

the "crater-floor," I consider I have pointed out the cause of the earthquakes. I think that no one could look at the circular wall of rock behind the town, could climb with painful steps its steep precipices, could view the shape of the depression he has risen from, and see the ruins of the town spread in a plain at his feet, could skip gently down the favouring slopes on the further side, and see the many parasitic cones on the flanks, without inevitably regarding the enclosed plain as the crater-floor. One has only to remember Monte Nuovo, to imagine one side broken down, and then to enlarge the whole ten-fold, to get an exact *fac-simile*. Moreover, though the whole volcano is now inactive, and the last lava, that of D'arso in 1301, is more basic than the mass of the island, yet there are still signs of heat at Casamicciola. Magnificent mineral hot springs of a temperature of more than 100° F., and of medicinal value, have made the place. Baths have been erected, and a strong stream impregnated with carbonates, etc., now rushes unconfined in the centre of the town, and through chambers where all is silent. If such be the true position of Casamicciola, it is not difficult to understand why there should be an earthquake there. A place which at any moment might revive its activities, and hurl the whole ground into the air, and throw it over Epomeo itself, is not likely to be a very steady spot; and for this reason I doubt if data obtained from here can be of any particular value as applied to other places. Dr. Lavis has prepared a most exhaustive and beautifully illustrated account of the earthquakes, which is published in a handsome volume. It is most important as a description of what I may call a crater-earthquake, but arguments hence derived will not at all apply to earthquakes in general, which do not occur solely in volcanic craters. Those who, like myself, had been in the habit of drawing a simple diagram to find the seismic centre, representing two houses at convenient distances, each with a simple crack, perpendiculars to which will meet in the seismic centre, *quod erat demonstrandum*, would be puzzled round Casamicciola. Treated in this way, the houses might show the centre to be in the air, in the sea, in the street itself, or nowhere at all, because the perpendiculars will not meet. Dr. Lavis, by making allowance for the positions of the houses, the nature of their foundations, the slope of the ground, etc., has concluded that the percussion

took place along a line of internal fissure, nearly perpendicular to the sea margin. Of such a line there is not the remotest indication on the surface, so that it is entirely theoretical. Far be it from me to say that by such observations one cannot localize the maximum intensity of the shock, but after a view of the ruins of Casamicciola and the country round, and after seeing the true record of the motion of an earth-particle in a quake in Prof. Sekiya's model in the Museum of the Science and Art Department, I do not think we can conceive of such earthquakes as modifications merely of a simple wave of percussion originating in a single spot or along a single line. At all events, in the case of Casamicciola, we can simply conclude that the shock originated within the crater at some distance below the ground; in other words, the equilibrium of the hot and possibly molten mass on the scum of which the town is built, was temporarily disturbed. It is not enlivening work to wander among the ruins, with their great gaping walls, opening into rooms filled with the broken roofs, or over mounds of rubbish, which in many cases conceal the bodies of the unfortunate victims, which were never recovered, still less so to pass along the deserted streets at night, when the deep shades throw the ruins into a thousand fantastic and suggestive shapes. At the time of my visit no attempt had been made to restore the ravages of the last earthquake. After that of 1883 the inhabitants were cruelly assured by an official geologist, in whom the wish was father to the thought, that all danger was over, and they began with enthusiasm to rebuild; but the still greater catastrophe which overwhelmed them two years later, dashed their hopes, like their houses, to the ground, and they stand still paralyzed. A couple of wooden buildings on open plots of ground near the sea represent the only hotels; the hospital is no more, and the inhabitants who are left, after the loss of 3,000 of their number, are collected in wooden earthquake-proof houses in little knots along the shore. Their misfortunes may be gathered from that of my host, who told me he was the only survivor of thirteen relatives, and on the fateful morning in 1885 had found himself in the street, his wife and four children and all his property destroyed.

I must now pass to the southern volcanoes. A most delightful steamer of the Florio-Rubattino Line takes you in a day's

journey from Naples to Messina, or to Reggio on the opposite side of the Straits, whence there is a ferry. My steamer happened to go to the latter, and I was glad it did, as it enabled me to form an idea of the possible cause of the Calabrian earthquake of 1783, of which so full an account is given in Lyell's 'Principles of Geology.' As this district is so near the line of volcanic activity, which may be supposed to pass from Etna to Lipari, it might be thought that the earthquake and those volcanoes were connected phenomena; but, as Lyell points out, there are here no volcanic rocks, and the proximity of the Neapolitan volcanoes has not availed to produce earthquakes in the solid limestone country around. But when we look at the coast of Calabria, an entirely different origin suggests itself. High in the background, as Dolomieu first pointed out, there are ranges of granitic and other hard rocks, on the slopes of which are the Subapennine marls which Lyell describes as bearing considerable resemblance in the yielding nature of their materials to most of our Tertiary deposits of England and France. Looking on these materials from the sea, after having become acquainted with their soft and incoherent nature inland, it was a marvel to me how they could possibly rest as they are without foundering, for they form very steep and irregular cliffs, and rise point above point to their backbone of granite. I am sure our Atlantic waves would make short work of the whole country. Accordingly we read that during the earthquake a huge chasm, from nine to ten miles long, was formed between the solid granite nucleus and the sandy soil. It is curious, however, that even Lyell, without apparently attempting to assign any cause to the earthquake, considers the landslip as one of its results, and not the earthquake the result of the landslip. Yet the position of the rocks, the limitation of the area affected, the phenomena produced, vast fissures, faults in buildings, chasms, circular ponds, currents of mud, new formed lakes, alterations of water-courses, all point to a shifting of the ground on a large scale as the cause of the earthquake. In this case, again, there is not much connection with an elastic wave of compression originating in a seismic centre. On the contrary, the origin of this noted earthquake is probably of the same kind as that of our minor English disturbances.

The eastern side of Sicily is composed of two distinct parts.

The northern is composed of stratified rocks, and the southern half is Etna. On the whole the succession of the sedimentary rocks is such that the newest are along or near the northern coast, and we reach older ones towards the south. The well-known Sicilian sulphur, with its beautiful celestine crystals, has no connection with modern volcanoes, but is a stratified deposit. Seeing, however, that it is of late Tertiary age, and that a few miles over the sea lies the still sulphur-bearing crater of Volcano, part of a widely spread volcanic group, we may perhaps conclude that the sulphur originated in a similar way in Tertiary times, and by many reactions it has finally again taken up its elementary form in the strata. In other words, though it is not directly formed from volcanoes, yet if there had been no volcanoes in the neighbourhood there would have been no sulphur.

The last point along the eastern coast at which the stratified rocks are found is at Taormina—a beautiful spot—a fashionable seaside resort, and the site of an ancient Greek temple. Here the rocks rise in lofty crags into the air, and, as seen from the south, form a cliff-like boundary to the view. Whether there is a real cliff there, now half obliterated by lava, or an ordinary fault I cannot say, but nothing more than volcanic products is anywhere seen to the south, except at low elevations along the sea-margin.

The usual method of ascending Etna is to take the train to Catania, thence hire a carriage to Nicolosi, about twelve miles on the road, and thence, under the conduct of guides, ascend by a gentle slope to the summit itself. The last stage below the final cone is the Casa Inglesi, or English house, 9,600 feet above sea-level, at which travellers might once rest for the night; but they now have to put up on a much lower level; for in the spring of the year, at all events, the summit of Etna is only on view from five a.m. to eight a.m., if so long. It is, therefore, necessary to sleep some distance up. However, after my experience of Vesuvius, and reading that only one man in this century had seen anything but steam entirely filling the crater of Etna, I concluded that more would be learned by exploring the Val del Bove, especially as time was limited, than by taking two or three days longer to ascend the highest crater. Nor do I regret the choice. I actually saw all I could have seen by the other route, and much more besides. The nearest station to that side

of Etna on which the Val del Bove is situated is Giarré. As the expresses stop here, I supposed it was a place of some importance, but I found it a mere village, with the most villainously dirty accommodation possible, which had the evil effect that I was obliged to make use too early of the tinned meats I had brought from Naples. I had an early view of Etna from this spot, and at six a.m. it was perfectly clear, with beautiful patches of snow on its flanks, and a curling white wreath of steam slowly rising from its crater. From this village there is a gradual ascent over sheets of lava and beds of tuff—which extend as far as the sea—for about eight miles to Zaffarana, a village at the bottom of the path which leads up into the Val del Bove. The villages have no inns, and the material to be obtained elsewhere is only to be eaten by a starving man, consequently I had to depend on what I brought with me all the way from Giarré till I returned there again. Were I making the journey again I should take a larger supply. However, there is a magnificent stream of water, which one follows for some way.

Starting on foot from Giarré at about six a.m., I spent some time in botanizing on the slopes, and looking at the wider-flowing lavas, which, being of more ancient date than those of Vesuvius, are more hidden beneath the soil. It was consequently afternoon before I began to ascend. The path leads by the side of an enormous lava-stream poured out in 1852, which dominates the route, and has changed the character of the whole valley. Under its overhanging eaves—for already the denudation in thirty-five years has worn back the softer rock below—hang beautiful fronds of maiden-hair, and delicate birch trees are found here and there. I find in every description of Etna that the cone is divided by nature into three distinct zones, called the fertile, the woody, and the desert regions. Of course it is true enough that at the base you find yourself in vineyards and orange groves, but there are also plenty of trees. As you ascend higher and really begin to climb the mountain, there is no more loose soil to cultivate. The slopes are rocky and the cold is more perceptible, and thus the land is left to nature and the sheep; but there is no forest. There may be a few scattered trees here and there, as on any mountain side, but shrubs and herbs deck the ground with

gaudy hues and green coverings, and continue to do so as far as I ascended—to 6,000 feet—gradually becoming fewer, as on all mountain summits, till snow prevents their growth. My visit was in spring; maybe there is still more vegetation in summer. Soon after leaving Zaffarana one has to climb on to the lava itself, and rise over the slope, down which it descended step after step—a rugged road, but perfectly accessible by ponies. At last, after turning the corner of the Sciuri Cosimo, an old cliff round which the lava was deflected, one stands on a ridge overlooking a fertile plain, with wheat and other cereals, and beautiful pasture for horses, watered by a little stream which rises at the base of Monte Calanna. This mountain and its higher neighbour, Zoccolaro, has formed a kind of buttress which has deflected all the flows. In most cases, however, as in 1702, 1819, and 1852, some portion of the stream has surmounted the ridge between, and poured into one corner of the vale. Still, a wide area is left untouched, an oasis in the desert of lava. This mountain of Calanna is of very old material. All is in a state of decay, and the percolating waters have caused the formation of beautiful zeolites.

I was fortunate on the occasion of my visit in having for the companion of my walk the owner of the valley, coming to look after his crops. On this upland valley he has erected a shanty, enclosed on all sides, but without windows, in which his man sleeps at night. I was able, therefore, to make arrangements with him to use this shanty for the night, and with his man to shelter himself elsewhere beneath some piles of brushwood which he had placed over a cavity in the rocks. After a preliminary climb into the Val del Bove to see the country, I returned here at dusk, and was safely shut in with a large bundle of brushwood which the man had meanwhile collected, and with which he lighted me a fire, and when he had brought me a large cruse of water from the spring, and shown me how to fasten the door, he bade me good-night, with the injunction to put on the wood as I wanted it, as I should be *freddi*. And *freddi*, indeed, I was, having left my overcoat behind, and having only a bundle of straw for bed and blanket. Here, however, I rested from seven p.m. to five a.m. in utter darkness, when I was called by the man, and found the sun shining outside. I give these details, because I am still

unaware how the glories of the Val del Bove with the crater in sight can in any way be explored at this, the best time of year for the general trip, without these or equivalent discomforts. Indeed, had it not been for this shed I should have had to descend some 2,000 feet to Zaffarana, and have lost the best time in the morning in gaining the spot again. As it was, after breakfasting, I made an early start at 5.30 a.m.

This lava-stream of 1852 is magnificent, stretching away in huge rolls right across the valley, almost as far as the eye can see. It forms a solid cascade of dark and rugged rock. This, indeed, was such a lava as I had expected to see, not the huge mud-heaps of the lower slopes, or the small ropy streams of the higher parts of Vesuvius, but a true scoriaceous surface, untouched by the weather or vegetation, and with no track upon it except that made by the footsteps of men and horses. On mounting the crest between Monte Calanna and Zaffarana the snow began to appear, and the lava not coming quite up to the cliff, left a pleasant pathway by the side of the old tuffs, buttressed again and again by the vertical dykes. At last the final slope is surmounted, and the full glories of the Val del Bove burst upon the sight. Lyell describes it as "more uneven than the surface of the most tempestuous sea." But this great lava stream of 1852, erupted since he saw the spot, must have entirely changed the aspect. The fluid mass must have been kept up by a ridge of rock extending from Cavanno on this side to Monte Fenoccio on the other, and have settled itself into a smooth and lake-like surface, over which the winds have spread a coating of the finest dust from the side; for the whole base is perfectly level, and would afford a hundred excellent cricket grounds if at a lower level. Across this trickle gentle streams fed by the melting of the snow, sinking somewhat into the loose, sandy soil; but this is easily excavated, and delicious draughts of water can be obtained. Tufts of grass diversify its surface, as well as numerous *Acanthus* bushes, which in summer time must be aglow with bloom. This plain of Trifolietto, as it is called, can no longer be described as a "dreary plain forlorn and wild, the seat of desolation, void of light," but more as "the open field . . . . enclosed with shining rock, a whole day's journey high," to quote the same poet. One of Lyell's figures, showing the view looking into the Val del Bove from above, is very characteristic

and recognizable, but the other figure, showing the view looking up the Val del Bove, is misleading, as the real valley is scarcely seen at all in it. It is taken from a point on the north-east, and the foreground, with the hills of Lepra and Musara, hides the valley. At the further end are seen the giant scarps, here standing out as huge buttresses, and here smoothed down with the screes of softer dust, and near them stand out upon the surface some old knolls, now clothed with birch, and elsewhere the remains of the orifices out of which the liquid lava welled. These latter are very instructive. They stand in a line one behind the other. The two outer are pointed peaks, called "Boccas" on the map, and such as are described as "Mamelons" by Judd. The three inner have the ordinary shape of craters. I did not have time to reach these masses, but they are thus described by Waltershausen :—"The highest is a little circular Bocca, and further away are three craters lying close together, one smaller and semi-circular, and two larger, extraordinarily regular cones, whose bases are in contact. These consist of brown and red masses of scoriæ, which in the upper part, by the action of the steam from the fumaroles, appear white or sulphur-coloured. The upper of the two craters, occupying the spot whence an eruption took place in A.D. 252, is called Monte Centenari, and is about 300 feet higher than the other. The summit of the first is about 800 feet above the plain of Trifolietto, while the latter only reaches to 250 feet. The upper cone has a round, not very deep, crater, while the lower cone has a nearly flat summit, in which scarcely any central depression can be observed. From these cones there were also minor flows of lava, which can be seen on their upper sides in several solid banks, lying like mantles round their centres. At the eastern foot of the lower cone lies the Bocca, out of which the mighty lava-stream poured forth, which is like a conical cinder-heap, and whose dark tint contrasts well with the true ash-cones in its immediate neighbourhood." It is very instructive to have the two forms of eruptive centres thus side by side, and to compare the effects. The results produced by the cinder-cones are confined to their immediate neighbourhoods, but, by comparison with the huge lava-sheet which has overwhelmed all the country as far as Zaffarana, the Bocca is quite insignificant. This is important to remember

when we find a difficulty in identifying the centre of ancient lava-flows, and seem to need some new theory of fissure-eruption to account for them.

As to the origin of the Val del Bove itself, my slight observations give me no right to dogmatize. Lyell denies that it is a crater, and accounts for it by the sinking in of the side of the mountain. This is on account of his observation that all the stratified tuffs have an inclination in the same direction, instead of the quaquaversal dip observable in the semi-circular Somma. To my eye these tuffs did not appear sufficiently well stratified to give any reliable data of this kind.

But all the dykes I saw, and all those figured by Lyell, run in a radial direction: none, or very few, are seen parallel to the side, which, if they originated in a spot beneath the present highest point they ought to be, all along the side up which one passes. Were all the dykes to be prolonged till they met, their average intersection would lie somewhere within the Val del Bove, especially if exception were made of those few which crossing others in their actual course in the sides may be reckoned as belonging to a different system. This and the numerous eruptions which have had their origin in the Val, show that at least there is here an easy outlet for the volcanic products. And after all, what is a crater? Is it not exactly a spot where the ground has sunk in, owing to the evisceration of the mountain by the outflow of lava, or the ejection of ashes? In this sense at least the Val del Bove is a crater.

It is generally stated that the sides of this great amphitheatre are inaccessible, but I found no difficulty in climbing one of the screes, by walking obliquely and so avoiding the huge stones which an incautious step will bring careering down from the slopes above, and the climb is well repaid. The early morning sun evaporates the snow, and raises the vapour in white fleecy clouds which have their birth immediately before you, and gathering in larger masses roll onwards towards the summit and finally shut it out from view. From the higher crests the new-born clouds are seen beneath your feet, and beyond them stretches a vast panorama, the equal of which I have never seen. To the left the lofty coast of Italy, beyond the Straits of Messina, on this side the low-lying outline of southern Sicily by Giarré, Ace Reale, to Catania, and then on

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by Syracuse, round Capo Passaro to Alicata, and as far, probably, as Girgenti. Nearer at hand the scrub-covered country, with nothing larger than tiny birches, stretches in a gradual slope, covered here and there with minor cones, as far as the more wooded district surrounding Nicolosi, where the country is more uneven. On the other side the gradual slope to the summit is so gentle that though one knows it is 4,000 feet higher, the ground to the base of the higher cone seems almost level, and sparkles everywhere brilliantly with the sunlit snow, and the crater itself is seen unclouded, majestic in its solitary grandeur, and sending forth a snow-white banner of fleecy cloud. It is, indeed, a noble mountain, the dirty Vesuvian heap it is almost bathos to mention in its presence, and it is hard to forsake the spot where it can be contemplated and admired. But nothing more can be done, the clouds are fast gathering round it, and by the time one has descended once more into the Val del Bove it is hid from view, though it is not yet eight o'clock in the morning.

The same night at twelve I started from Messina for Lipari. It might be thought that after the mighty Etna, the miniature volcanoes of Lipari would have nothing equally good to show. Equal, certainly not, if the scale of operations is the test of goodness; but small though they are, these island outbursts are overflowing with interest. The Liparotes themselves are a fine race of men, very different to the dirty Neapolitans or the grasping Sicilians, and there is a sense of rest and homeliness in the very surroundings, and for volcanic phenomena they are quite unique. There is no special centre in Lipari, but numerous little mouths each contribute their special flows or heaps of dust to the building of the island. Its surface is thus very diversified and beautiful, the valleys have no predetermined form as when they are due to denudation, but each has a special character of its own, and many doubtless might be lake-filled hollows were it not for the porosity of the soil. This, too, is the kind of home to protect a varied flora, and even in spring time the gathering that may be made is very rich. However, it is not the beauty of the island, nor its ordinary lava-streams and cones of tuff which are the chief attraction. It is here that we can best study the nature

and connection of two of the most remarkable of volcanic products—obsidian and pumice—neither of which has made any show, though actually obtainable elsewhere. On the origin and connection of these two my visit to Lipari has entirely revolutionized my ideas. Much semi-glassy rock may be seen in the neighbourhood of the town itself. It is full, however, of spherulites, and these are arranged in numerous parallel bands, which in the flow of the molten mass have suffered the many and strange contortions so well figured by Prof. Judd. These banded spherulites are indeed the characteristic rock of the island; they occur everywhere, and often go by the name of obsidian, though Judd calls them rhyolites in the explanation of his figures. It is the same rock, however, at the Rocci Rossi, which we come to presently. The abundance of these banded spherulites was especially interesting to me, because they exactly call to mind the masses in Ramsey Island of apparently pre-Cambrian date, which I have described as making so magnificent a display in Pwll Hendro. Indeed, except for its faults, Ramsey Island would be a good miniature of some parts of Lipari. As for the black obsidian glass so well known in collections, I found it quite rare; almost every flow is spoilt, so to speak, by these abundant spherulites, and only at isolated spots a small piece of pure glass may be obtained. The specimens in collections must be obtained from ejected blocks, from which I procured my own; one of these on the summit of the pumice cone was very large, some 36 cubic feet, others on the slopes and scattered over the island are much smaller. When these large masses of true obsidian are seen the impurities are found to consist not of spherulites, but of froth, which becomes so abundant in places as to remind one of pumice. Hence I imagine they do not belong to the same masses as those which show the spherulites. I take the spherulitic rock to be the more common one, and obsidian the rarer.

And now for the origin of pumice and its relation to the true obsidian and the spherulitic rock. The home of pumice is the Campi Bianchi, on the opposite side of the island to the town, at a distance of about three miles, the outer slopes facing the sea. It is, as every geologist knows, a

cone of ejection differing only from ordinary cones in the fact that the fragments are pumice and pumice-dust, and from Monte Tabor in Ischia in the pumice being non-porphyritic. This soft dust is deeply scored by streams, one of which gives a magnificent section of its outer slopes, showing it to be built upon, though it does not consist of the spherulitic glass. It is still further scored by the excavation of pumice and the roads and pathways worn by the workmen as they pass and repass. The whole of the pumice of commerce is obtained from diggings in the loose pumice dust; when found it is in lumps seldom larger than a man's head, more usually of the size of a large cricket ball. In other words it is all derived from ejected blocks, which have suffered a long process of weathering which has bleached them to their present tint. If such be the case, what is the original rock? From what I had read I had supposed that I should find pumice *in situ* on the surface of the black obsidian glass. But as it happened, the day I went to explore the Campi Bianchi was a very wet one, and mists covered the whole ground, so that I could scarcely see far before me, and thus I was on the pumice grounds before I knew it. In the deep gorge, up which I climbed, I was struck by the extraordinary massiveness of a peculiar rock I had never seen before—some scores of feet of which were seen in unbroken continuity, and which cropped out again and again at intervals of over a hundred feet. Near the summit of the slope there are two caves in it out of which steam still issues with a dull roar like a miniature solfatara, and the rock around is still warm; so that the volcanic activity of Lipari is not quite extinct or limited to the hot springs on the western coast. This massive rock, which thus appears to constitute the bulk of the hill, is very uniform in structure, and the bands of it are not contorted, but it is of a spongy nature, viz., a glassy rock with gas-cavities distributed through it with perfect regularity, and each cavity is elongated in the same direction. It is light brown in tint, and would easily weather white. On my reaching the summit-level the clouds suddenly lifted, and I found myself standing close to the edge of a perfect crater, whose steep sides descended close to my feet, and at the bottom lay a black mass which could be traced away to the sea. In a moment I saw I was already on

the edge of the Campi Bianchi itself, and the meaning of the rock I had seen became clear. It is pumice *in situ*. It is the normal rock whence pumice is derived, and black glass obsidian is an accident. It is not that pumice is formed from obsidian, but obsidian is produced by the later melting of the pumice. I afterwards examined the Rocci Rossi at the base, and found it to consist of the glassy spherulitic rock I had so often seen before. It would never form a pumice, nor be formed from it. It is associated with the pumice, yet of a distinct formation. This massive "mother-of-pumice rock," as I christened it on the spot, I had never seen before, and had never heard of its existence. I believe it is what is called "Bimstein-Trachyt," but for which we have no English name. It thus becomes clear why pumice is so much more widely spread than obsidian, which would be somewhat remarkable if it were derived from the latter. We know there is plenty of pumice on Vesuvius and also on Ischia, and yet it is very hard to find anything approaching to obsidian. As far as I could see this mother-of-pumice rock in the Campi Bianchi showed no signs of having flowed, though the elongation of its bubbles might suggest it. It seemed rather to have formed in masses on the spot and, therefore, under pressure, which would equally account for the elongation. I would, therefore, propose the following explanation for consideration. Here we have a rock formed by the interaction of heat and water on a liquid mass, so that the bubbles of steam are uniformly distributed, and yet not allowed to escape, and the rock itself has consolidated underground and has only reached the surface in accidental spots. In some cases many of the bubbles have run together and have left the enclosing glass to amalgamate and form what we call obsidian. Thus obsidian would not often be expected, being an accident, and mother-of-pumice would never be seen on the surface, but only in later excavations by the weather. If this be the case, Monte Tabor in Ischia, which is not as yet scored like the Campi Bianchi, ought to show this rock, and not obsidian, if a section were cut into it.

The Campi Bianchi is the only pumice-bearing hill at present worked, and there is still in it a supply to last for many years, so that the neighbouring hills, whose pumice is inferior, are likely to be left untouched, but they are on a grander scale,

and the streams have cut in them deep gorges several hundred feet in almost sheer descent, between which the narrow *arrêts* are dangerous walking, and their brilliant white colour, when the sun shines, reminds one of the purest chalk.

Overlooking this side of the island is another volcanic mass, forming the island of Salina, so called because of its ancient evaporating-pans for salt. I did not visit it, but took the steamer that calls at all these islands, on board of which in the early morning there are grand views. The finest is that in which Etna and the Lipari group are seen in one picture. From hence, also, is seen the relation of the Rocci Rossi to the Campi Bianchi as figured by Judd. The northern islands are formed by two volcanic centres; one is Stromboli, which I had to omit, the other is a broken group consisting of Panaria, Lisca, Baziluzzo, etc., all fragments of one mass now sunk beneath the sea, the still emerging islands being the highest points of the crater-ring, and the fishermen declaring that in clear weather the tops of ancient buildings may be seen erected on the crater-floor of pre-historic times. As I did not see them myself I cannot vouch for the truth of the statement; though I think it not incredible. I landed on Panaria—so-called because they grow corn there and so supply the neighbouring islands with bread—because I was told that true liparite, *i.e.*, quartz-rhyolite, is not to be found on Lipari, etc., but on Panaria. I certainly obtained several varieties of trachyte, and some of them are quartz-bearing.

The final, and in some respects most interesting, visit was that to Vulcano and its attached Vulcanello. For this a boat is necessary. The principal attraction here is that, though the volcano is in activity, you can descend into the crater. The general structure of the island, with its successive cones along a straight line, and the shifted craters of Vulcanello have been well described by Prof. Judd. At the time of his visit the volcano was behaving well, and sending up vapours with so great regularity and quietness that works had been erected over the fumaroles and the precious products collected. But all this was changed a year before my visit, for while the works were going on, while the foreman and the men were in the crater superintending the collection of the gases,

there was heard a low rumbling sound below, which led them to rush away to the sides of the crater, and they had scarcely escaped when, with one great outburst, all the houses, factories, plant, and even the ground itself was swallowed up and a great roaring rush of sulphurous steam hid everything from view and drove them from the ground. When I went there the volcano was still digesting its meal, almost all the work on the island had been stopped, except the collection of sulphurous vapours from the minor fumaroles on the side whence, mixed with arsenic, it is constantly escaping. This, in fact, like the Solfatara and Vesuvius, is a chemical volcano of which sulphur is the principal product. Mr. Narlian, the resident owner, has been waiting, I suppose, for the volcano to quiet down again, to re-open the work; but, if so, he must have been disappointed, for since my visit worse catastrophes have overwhelmed him, the account of which from himself, an eye-witness, is so interesting that I may be pardoned for transcribing it at length.

Lipari, August 30, 1888.

My Dear Dr. Johnston Lavis, I have your kind note of 22nd inst., and will give you a short account of the strange doings of our old friend, the crater of Vulcano.

On the 3rd inst. we had an outburst in the crater with stones, flames, thunder (regular lightnings). It was strong enough to throw stones of considerable size to the sides of the mountain. This lasted perhaps ten to fifteen minutes, and then ended. After some time we began to have, at the interval of every twenty to thirty minutes, a great rush of thick smoke, and lasting some ten to twelve minutes at a time. We had often seen such eruptions during the twelve or thirteen years I have been on this island, and I hoped it would end like former eruptions. Towards evening, however, these rushes of smoke, steam, and ashes (which used to be projected into the air to about twice the height of the mountain) had completely ceased. As the night approached the leading fumarole (which was very active, giving off an offensive smell for months before the event) had begun to show a *clear high flame*, much paler than the flames produced by the burning of wood, and somewhat greenish or bluish. This phenomenon, together with the sudden stopping of the smoke, was evidently not a good omen. . . . Towards morning . . . I was awakened by a tremendous din . . . an indescribable noise of thunder, rush of gases, flames, falling of huge boulders, rocks, etc. . . . (all these stones are quite red with heat). . . The house doors were shivering and shaking, so that it was a difficult matter to open the doors. At last I succeeded, but before we were out on the verandah another stone fell at our feet, was smashed to fragments, and burned the feet and legs of my boys. . . . Another stone fell very near us (none of these stones were less than two feet in diameter). . . . By this time (not many minutes after all) the whole place was lighted up—woods, grass, buildings, hedges—all was on fire; the huge boulders and stones were literally raining everywhere about us. . . .

On revisiting the spot I saw the whole plains below the mountain, to the distance of one-and-a-half mile . . . literally covered with boulders and rocks

of all sizes, which had embedded themselves in the ground to various depths. The most huge of them . . . is not less than ten yards in diameter, and is some ten to eleven feet deep in the ground. This is about three-quarters of a mile from the crater. Another, of nearly equal dimensions, is on the shore near the Quarantana, at the end of the bay of the Levante! Rocks of one yard in diameter are as plentiful as can be as far as the middle of Vulcanello, near the Punta Samossa! . . . After this awful calamity . . . the crater has recommenced the rushes of steam, ashes, etc. This was a time of comparative diminution of activity, which had lasted for some days. Soon, however, it began the old game of throwing stones, boulders, ashes, etc., every two or three minutes. . . . No doubt many of these boulders are ten to fifteen yards across, and are projected as far as the sea, but often fall back into the crater itself. This state of things is continuing incessantly and uninterruptedly. . . .

During the last three or four days the noise of the thunder and eruption is so loud that from Lipari (at the distance of six miles) it would be impossible to distinguish it from a prolonged thunderstorm.

Yours truly,
A. E. Narlian.

When I visited the volcano I entered the crater by a well-made path, and, though the sides were approachable, the centre was still roaring with a horrid sound, the sides were all clothed with precipitated sulphur, and yawning cracks, filled with fetid vapour, divided all the floor. The noise appeared greater than that of Vesuvius, and I wished to go nearer, on to one of the spaces between the cracks, and peer down and see, if possible, any boiling mass below: but, after prodding a few steps in advance with his stick, my guide said it was doubtful if it would bear, and that, if it did not suddenly fall into the abyss, we might sink in the loose sulphurous dust and have some difficulty in getting out; so I had to be content with a view from the side, and this, with the great walls rising high above me into the sky and steaming above, below, and all around, was grand enough.

And so came an end of all I could do in visiting Italian volcanoes—enough to whet the appetite, to open the eyes, to render more intelligible the description by closer observers of volcanic phenomena, but far too short to satisfy, or give one the faintest belief that the subject was mastered.

Note on a Chelonian Humerus from the Middle Eocene of Bracklesham.

By R. Lydekker, B.A., F.G.S.

(*Communicated by* A. Smith Woodward, F.G.S.)

(*Read May 3rd, 1889.*)

I have been requested by Mr. A. Smith Woodward to describe the imperfect humerus of a large marine Chelonian, the property of Mr. J. B. Ogle, obtained from the Middle Eocene of Bracklesham, in Sussex, which, as I am informed, was exhibited at the meeting of the Association when Mr. Woodward read his paper on 'Leathery Turtles.'*

This specimen, of which a reduced figure is here given (Fig. 1), is the left humerus of a member of the *Chelonidæ*, or true turtles. It has lost the distal third; and the proximal extremity, and more especially the head, has suffered considerably from erosion, by which its original contour has been somewhat marred. In size this specimen agrees approximately with the humerus of the largest skeleton of *Chelone mydas* in the Natural History Museum. This feature alone suffices to distinguish the specimen from the turtles of the abundant Eocene genus *Lytoloma* (*Euclastes*†), the largest forms of which are characterized by the small size of the shell and limbs in proportion to the skull. Further, a comparison with the figure of the corresponding humerus of the Eocene genus given by M. Dollo in the 'Geological Magazine' for 1888, p. 266, fig. 2, will show better than any description how widely the present specimen differs from that bone; the

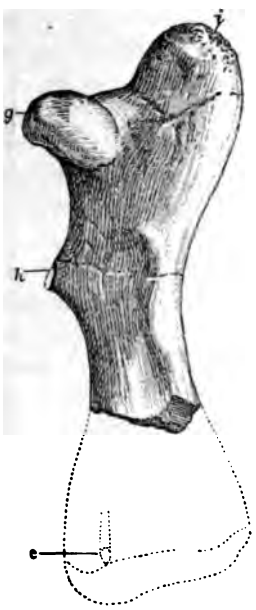


Fig. 1.—Left humerus of *Thalassochelys eocænica*.

* 'Proc. Geol. Assoc.,' Vol. x, p. 2.

† For the complex synonomy of this genus see 'Quart. Journ. Geol. Soc.,' Vol. xlv (1889), pp. 233-234.

most striking differences being the lower position of the radial (lateral) process, the less constricted shaft, the more prominent ulnar (mesial) process, and the smaller obliquity of the head.

Compared, however, with M. Dollo's figure of the left humerus of *Chelone mydas* given in fig. 3 of the page cited, a much closer resemblance will be apparent. The present specimen differs, however, from the humerus of *Chelone* by the more marked constriction of the shaft below the radial process, and also by the circumstance that the head is placed more obliquely to the axis of the shaft; in consequence of which latter feature more of the head is seen from the dorsal aspect of the bone here figured than is the case with *Chelone*.

In the points in which this specimen differs from the humerus of *Chelone* it resembles that of the Loggerhead Turtle (*Thalassochelys*); and there is accordingly a *primâ facie* case for referring it to that genus. There is, moreover, certain additional evidence in favour of this reference, since the British Museum possesses a portion of the mandibular symphysis (No. 38,995) of a very large Chelonian from the London Clay of Sheppey which agrees so closely with the mandible of *Thalassochelys* that there can be but little hesitation in referring it to the same genus. It does not, indeed, necessarily follow that this specimen belongs to the same species as the humerus before us, but it is important in confirming the evidence of the latter as to the existence of Loggerhead Turtles in the Eocene.

Since I am unacquainted with any described European Eocene Turtle with which the humerus under consideration can be identified, I venture to regard it as the type of a new species, for which the name *Thalassochelys eocænica* will be appropriate. I shall not, however, attempt to define this species from the evidence of the humerus alone; taking it for granted that it must certainly have been distinct from the existing species. At the same time it must also be assumed that this form is specifically distinct from all the Eocene Turtles of North America, none of which, so far as I am aware, have been referred to *Thalassochelys*.*

Finally, the rarity in the English Eocene of remains of turtles

* Two of the English Eocene species of *Lytoloma* were referred by Prof. Cope to *Thalassochelys*.

allied to existing types lends confirmation to the suggestion made by M. Dollo that the members of the genus *Lytoloma*, which are comparatively so common in those deposits, were mostly of estuarine habits.

On Rocks from the Saas-Thal and Geneva.

By Captain Marshall Hall, F.G.S.

(*Read May 3rd, 1889.*)

I can do but little on this occasion beyond describing these rocks, since Prof. Bonney's recent paper (far more elaborate than I was led by the abstract to think it) upon two complete traverses of the Alps,* renders my own proposed account of one half-traverse of the Pennine range so small a matter comparatively that, for the present, I put the restraint of silence upon myself. But an account of rocks under the microscope may always be of use to other workers, and may at a future time be appropriately followed up, after, if possible, another visit to the localities. Indeed, deep snow and a change to bad weather in 1880, prevented me from carrying out field work with anything approaching to completeness. Of course, drizzle, showers, and sleet or snow, which at lower levels simply cause discomfort, take forms at high altitudes which render satisfactory work impossible.

I may be allowed a reference to my very small share in the literature of our subject. My first visit to the Saas-Thal was in 1849, and the object which led to my second visit in 1880 was in great part to trace home the very interesting erratic stones scattered by the retreating glaciers on the north side of Lake Leman and at Geneva. The year after this visit I read a paper before the Société Vaudoise des Sciences Naturelles at Lausanne, and contributed a short account of it to the Mineralogical Society, which appeared in their Magazine for June, 1883. Since then one thing or another has prevented me from revisiting the locality. I have induced my friend Mr. Grenville A. J. Cole to go through my series of euphotide and schistose rocks. He brought to bear upon them the skill of his special work, and that comprehensive shrewdness in the application

* 'Quarterly Journal of the Geological Society,' Vol. xlv (1889), p. 67.

of evidence which is the glory alike of lawyers and men of science.

It is difficult to separate my friend's contributions from my own. As a rule, wherever special microscopical detail is given, and deductions therefrom, it will be safe to attribute these to Mr. Cole, and ordinary work and painstaking to myself.

Leaving London in the morning one can reach Visp, at the foot of the Saas-Thal, on the afternoon of the next day, and even walk one hour-and-a-half up to Stalden, to sleep. From this latter place a beautiful walk or ride of four hours will bring us to Saas-im-Grund, on the verge of our happy hunting-ground. Another three hours, during which the scenery becomes more and more wild, and we shall be at the Mattmark Hotel, the highest in this valley, at an altitude close upon 7,000 feet.

I have sketched the details of the journey in the pages of the 'Geological Magazine' for June, 1889, as also the easy ascent in three to four hours of a point marked 3,150 metres (= 10,333 feet) in the Swiss official map. This, a prolongation of the arête leading up to the Allalinhorn, and surrounded by great glaciers, would, as I have before described, seem to be the source whence the euphotide and other gabbros have been transported by ancient glaciers to Geneva. It must, I think, be an intrusive mass, surrounded, so far as ice will allow us to see, by serpentine and various schists. But of all the specimens I could collect, not one appeared to be an unaltered rock. I will first take those cases in which the least alteration shows itself.

Slide 1, from the *débris* at the foot of our point, happens to show one of the least altered instances of the green mass commonly called smaragdite, together with that known as saussurite, side by side, though slightly crushed, as they arose from their respective originals of diallage and lime-soda felspar. Mr. Cole remarks that from such a rock one may be able to trace the pyroxenic and felspathic decomposition-products, in cases where all original juxtaposition and structure is masked and destroyed. With regard to the saussurite and smaragdite, it may be as well to recall to mind that the minute study of both these shows that they are not simple minerals. For an account of the former I cannot do better than refer you to Mr.

Teall's 'British Petrography,' where its history is well given; and to Rosenbusch, Vol. ii, p. 163, *et seq.* He derives saussurite-gabbros not only from gabbros themselves, taking them as a triclinic felspar and diallage, but also partly from diabases, saying that this is easily explained from similarity of chemical and mineralogical constitution, and undergoing similar geological processes. Saussurite may be taken as a mixture of an altered plagioclase, in some cases labradorite. Smaragdite has been made out to be in the form of diallage, and to consist of alternate laths of hornblende and augite (Omphacite). I refer to Rosenbusch, Vol. i, p. 466, who notices the occurrence of rutile in this mass. In this slide there occur yellowish, somewhat rounded bodies, well seen under a power of about × 300, which I could by no means name, till Mr. Cole, with youthful but experienced eyes, observed, under high power, in other specimens, thoroughly well formed and characteristic crystals of rutile, on comparing which with other slides it became evident that titanium is a common constituent of this rock and locality. Probably rutile has taken the place of ilmenite, the presence of which I do not call to mind.

Slide 2, from the same spot, is chiefly smaragdite, and is the specimen in which Mr. Cole found the yellowish-brown mineral to be exquisite twins of rutile, geniculated and even heart-shaped, of most characteristic form. Titanic iron in basic rocks may, on its destruction, yield soluble iron-compounds, which disappear, and TiO_2, iron-stained, is formed, as in these dark little rutiles. This euphotide is full of parallel-lying delicate prisms like actinolite. We have great cracks and signs of squeezing, the hollows probably converted, at the time of production, into receptacles for new crystallizations.

Slide 3, from the same place as both the others, but still nearer to a fresh exposure of the parent rock, which is inaccessible on account of an intervening crevasse in the glacier. Saussurite, with well-developed prisms of what Mr. Cole agrees with me in considering to be zoisite, well-developed, in places. Also one or two highly refractive yellow-brown granular groups, which may be a ferriferous epidote, somewhat like piedmontite, but giving no pink tints in pleochroism. These, I am told, resemble the brown mineral which Prof. Bonney has left undecided in the glaucophane-schists. They were thought

to be pseudo-brookite in some schists from the Val d'Aosta, belonging to Mr. Cole. I confess I felt doubtful, after his identification of rutile, whether they might not be something of that kind.

The following specimens were all broken from the rocks *in situ*. They show that, whatever the heart, so to speak, of the mass may be, its outer portion is by no means typical gabbro.

Slide 4, from its base, is close upon being a glaucophane-schist, according to Mr. Cole, who, however, remarks that the hornblende is a little too green, and more like actinolite. But it is decidedly bluish, like the glaucophane from Zermatt. There is pale yellow highly-refracting (pitted surface and dark outlines) epidote; also some pale yellow isotropic garnets. The streaky, nearly colourless green substances are probably chlorite. There is a white mica, and one bit of magnetite shows so brownish a lustre by reflected light, that I suspect it of being in the titanium interest; also dark brown rutiles. The glaucophane, amphibole, and epidote closely resemble well-known glaucophane-schists. See Prof. Bonney's Aosta and Zermatt papers.

Slide 5, from a very little higher and more to the right (I give these details to assist on future visits), which is well suited to the half-inch objective, is nearer to the gabbro nature, giving a mixed saussuritic mass, with much green hornblende and nearly colourless mica. Mr. Cole remarks that its probable origin may have been a gabbro, not over ferruginous, and without olivine. The appearance of the hand specimen was as of a gabbro.

Slide 6, from a couloir on the ascent, contains what resembles a smaragdite, either as a pseudomorph or squeezed by the felspars. It is too far altered to be described by one name, and consists of brightly polarizing hornblende, mica, and what looks like zoisite, much mixed. There are numbers of minute rutile crystals, a pale actinolitic hornblende, and a white mica, which Mr. Cole does not consider likely to be a muscovite. As I have found in sundry of these rocks, there is some secondary calcite, verified by Mr. Cole, which is somewhat pleochroic.

Slide 7.—Higher up the same couloir we come upon a fine-grained schist, with colourless hornblende (see cross-sections here and there), with faint blue tint in places, near glauco-

phane. Another colourless mineral, with low polarization colours, seems to be zoisite. The extinctions are also rather those of zoisite than of epidote. There is a white, bent, twisted mica, with pink and green polarization colours. This is abundant. Here, again, Mr. Cole is suggestive. He says: "Does this rock result from re-crystallization and re-building of a lime-magnesia-alumina-silica rock (such as a dolerite poor in iron)?"

About half way up our ridge we find a crushing, which gives rise to bending of the grey mineral of *Slide* 8, resembling a flow The fine fibrous refracting prisms lying lengthways in this section are probably zoisite. (See one or two cross-sections.) The yielding mineral of the mass appears to contain calcite.

Lastly, I must describe a specimen (*Slide* 9) from the summit, by which I rather mean the ridge than anything approaching to a peak. Here we have a thoroughly crushed schistose rock, bearing signs of metamorphism from gabbro, with granular crushed re-organized felspar, as well as true quartz, and pale elongated crushed hornblende, with cleavages in cross-sections, and some pleochroism. The whole surface of this crag is covered with large blocks, disintegrated from its mass.

I will describe three specimens more from the moraines immediately neighbouring to our crag.

Slide 10, from the Allalin glacier, contains much smaragdite, with actinolitic fibres, replacing the old pyroxene, of which a little grain of cleaved augite remains to testify. Near this is a granule of iron-pyrites, and many small crystals, geniculate and heart-shaped, no doubt of rutile.

Slide 11, from the glacier of Hochlaub, presents a saussuritic mass, with cavities filled with pale brown mica and colourless hornblende, the first lining of these cavities being a zone of garnet. Mr. Cole remarks that the areas represent a very pleasing case of secondary reconstruction of pyroxene, or olivine rebuilt.

The next rocks to these euphotides are serpentine, passing into schists.

Slide 12, from the side of Allalin glacier, is a typical serpentine, in which the original olivine and enstatite grains are

entirely obscured, the "Balken Structur" of recrystallized matter (chrysotile) being clear under crossed nicols, and very characteristic. The magnetite, altering to brown streaky oxides, results, as usual, from the ejection of iron once held in the olivine, during serpentinization. There is a trace, as seen in our Lizard gabbros and serpentines, of a dusky, fibrous mineral, once bastite or diallage.

Any of my colleagues visiting this magnificent scenery would do good service if they would explore this ridge as far as the top of the Allalin-horn, 13,231 feet, and ascertain the relations and variations in composition of these rocks. Starting early, say 4 a.m., from the Mattmark Inn, they would be on the top of point 13,150 feet by seven or eight o'clock, and could devote a summer's day to this field work. If it be practicable to descend from the Allalin-horn on to the glacier of the same name, as probably it is, a good round might be completed by so doing, and returning by the Inner Thurm (the usual route to or from the Allalin Pass); or, if they wished to leave the valley, they could, of course, take that pass to Zermatt or the Riffel.

Not connected immediately with these gabbros are three Saas-Thal rocks which are worth describing.

Slide 13 is from lower down the valley. This rock exists in some mass, intercalated between the older schists, and apparently more than a vein, but not worked out by me for want of opportunity. It is a handsome quartz-muscovite-garnet, the mica somewhat sparse. The quartz, Mr. Cole remarks, is such as might have arisen from that in an igneous (or the sand-grains in a sedimentary) rock, and, of course, the garnets are the common metamorphic product. Reconstruction has gone on during earth-movement and squeezing.

Slide 14.—A crushed rock, also common lower down the valley, such as might result, as Mr. Cole says, from the complete alteration and deformation of a diorite. Quartz, green chlorite, which has been formed from altered biotite, which latter remains in one or two patches; felspathic granules, magnetite, iron-pyrites in cubes, and a mineral like garnet, but more prismatic and by no means isotropic. What is this? Can it be tremolite, or even epidote? Muscovite is also present, colourless, with pale delicate pink and green polarization colours.

Near Saas-Fée occurs a sparkling reddish schist, of which *Slide* 15 is an example. It resembles so-called avanturine quartz of Siberia, which has similar red sparkling streaks from alteration of mica; much of this red oxide is probably from its decomposition, both muscovite and some colourless biotite still remaining between the quartz-grains. There occurs a scattered, palely polarizing, highly refractive mineral in bluish-grey granules, which has not been determined. These granules resemble garnets, such as occur in quartzites and granulites, but are not isotropic.

Slide 16.—This was found in the valley, not *in situ*. It is an altered saussuritic felspar, with some hexagonal crystals—sections of octahedra, non-polarizing, with inclusions which appear to be small garnets. Groups of larger ones occur in the same rock.

I must exemplify to you how entirely identical are the corresponding Genevese erratic rocks. The easiest hunting-ground is a stony plain at the junction of the rivers Arve and Rhone, a quarter-of-an-hour's walk below the town of Geneva. Last summer was, as I expect the coming one will be, a propitious time, since the Government are dredging the Rhone-bed, and even very large blocks are landed, so that fresh pabulum is being afforded to satisfy the appetites of collectors. This spot is meeting ground for stones from the Canton Valais, brought by the Rhone glacier, and for others brought by that from the Mont Blanc range, which followed the course of the modern Arve.

I select a few slides to exemplify similarity with those *ex-situ* which have already been brought under your notice. And first, *Slide* 17, is a typical gabbro, with altered diallage, smaragdite, and dusty saussurite, in which zoisite is seen in prisms brilliantly polarizing like fibres, though one must not be too sure without separation and micro-chemical analysis, in clear, fresh patches. Colourless garnets occur in zones of interaction, but for our purpose it is needless to go much into detail. The hand specimens of this and of number 6, already described, could scarcely be distinguished, though the microscope reveals some difference.

Slide 18 compares with 11. Zone of garnet in cavities of secondary crystallization, resembling the "Flaser Gabbros." With regard to this word I have only found it in one German

dictionary, which referred me to *flader*—streak—vein-spot. Mr. Teall, in his 'British Petrography,' pp. 176-8, gives a full account of this structure. There are three definite steps—flaser-gabbro, augen-gabbro, and schistose-gabbro—before we lose sight of that rock.

Slide 19 is a metamorphosed gabbro, with semi-metallic sheen by reflected light.

Slide 21, from Geneva, I merely show you as erratic and resembling 12. Near the eastern extremity of Lake Leman, at Veytaux, rocks from our district are scattered up to a considerable height. *Slide* 20 is from such an erratic block, and resembles 11, but is of a finer grain.

There remain three rather poverty-stricken specimens of the cutter's art, done for me at Geneva, from pieces of which we have the hand-specimens here to-night.

Slide 22 resembles 1, but is clearer. Garnet zone and a little colourless mica.

Slide 23 is a saussurite, very badly cut indeed. Garnets in the contact zones.

Slide 24, the last I need trouble you to consider, is a decomposed and a recomposed euphotide, with much pale mica, and at $\frac{25}{31}$ a granule, of which the colours between nicols are perhaps scarcely high enough for glaucophane. If it be not this there is difficulty in determining its identity. Can it be andalusite? Green chlorite appears in the decomposition-cavities. Mr. Cole reports zeolitic areas, giving groups of tufty fibrous crystals, noticeable under crossed nicols. Pyrites is also present, as also rutile.

I am exceedingly sorry not to produce a duly illustrative series of the rocks themselves. But, as a consequence of rather a vagabond life for the last ten years, my collection is scattered. Some are in Devonshire, others in Switzerland, and my choicest packet of specimens was posted at Saas in the year 1880, and has not arrived yet. Should I be able to revisit the Mattmark district I shall hope to lay before geologists fair samples of the country and to verify or disprove conclusions which it would be unwise to lay crudely before you on this occasion, the more so since we could only appeal to the evidence afforded by the microscope, which it should be a canon never to do without confirmation. But I hope some of my audience may be induced to visit those noble scenes themselves, in which case, though out of the scope of this paper, I

venture to implore them not to return without seeing either the view from Monte Moro, a couple of hours' or so walk from the hotel, or to take the new Weiss-Thor Pass to the Riffel or to Macugnaga. Nothing I have suggested in this paper calls for first-rate mountaineering—fair strength and activity are, of course, necessary, and guide-power of good quality. We have seen that this gabbro mass passes occasionally into schists, when it becomes glaucophanic, to which end labradorite felspar probably contributed. At this spot the crushing has been less than is found in more southern areas, the schistose appearance being occasional rather than persistent. These rocks correspond to, and are typical of the old gabbros of Von Buch, and the freshest of them is far from the types of Volpersdorf, not to mention Skye. The age of these rocks is greater than that of the schists generally considered Triassic, met with in the lower portion of the mountain flanks, as may well be seen in ascending the valley of Saas; but they are, of course, younger than the central gneiss of the Western Alps. Gerlach divides the schists of Canton Valais into (1) those of Lory, Triassic, (2) the younger, and (3) the older-metamorphic Schists. This succession is generally accepted. As regards geological age, *sub judice lis est.*

Notes on Early References to Geology, mostly before 1800.

By Edwin Litchfield.

(*Read May 3rd, 1889.*)

I fear the name given to this paper will lead you to expect more than I have collected. It really is a few brief remarks on older writings on the subject: a few extracts from prose and poetry touching upon geology and geologists, and all the reviews I can find in the Annual Register, from its first number in 1758 to 1801. I was in hopes to have found the word "Geology" to have been of English construction, like "Telegram" or "Telephone;" but there are two books in the library of the British Museum—one 'Geologia del Dottore,' etc., by Don Fabrizio Sessa, Napoli, 1687; the other 'Geologia sive Philosophemata de Genesi ac Structura Globi Terreni,' by Dethlevo Cluvero, Hamburg, 1700. Nor can we take these two books as being the first in which "Geologia" has been made use of or described.

There are two other books in the Museum amongst many: Georgius Grobius, 'Theoria de Fossilibus,' 1593, and Llhwyd's 'Ichnographia,' 1699. Grobius refers solely to metals and stones. Edward Llhwyd,* a great writer and archæologist, deals with fossils, classifying them as Lapides, Chrystalline, Coralline, Lithophyta (leaf-bearing), Turbinata (turbans), as ammonites, Bivalvia, Crustacea punctulita, *i.e.*, Echinodermata, Ichthyodontes cuspidati, Ichthyospondyli, etc. By other writers there were various theories held as to the growth or making of fossils. There was a germ theory that the germs fell into the cracks in limestone, and grew to a size, and died from want of room. Another that the shells existed previously in the ocean, that they became dissolved in the great flood, and were held for a time in suspension, and afterwards subsided and arranged themselves under the laws of gravity. The fact of finding rocks and even mountains "infested" with sea shells must always have been a puzzle to man, and a subject on which he could start any theory of his own; and it is by no means to be wondered at that the first impression was a general flood, and the sea covering the land to a great height. Even as late as 1799 Richard Kirwan concludes from his observations on fossils that no fish appeared in the sea until the original ocean had subsided, leaving the mountains 8,500 feet out of water. The shaping of the globe into continents and islands, mountains and valleys, and the depths of the sea are attributed by him to great shocks. England received one of these shocks 3,600

* Edward Llhwyd, born in 1670, died at Oxford, July, 1709, Student of Jesus College, 1687; succeeded Dr. Plot as Keeper of the Ashmolean Museum about 1690; travelled in Wales, Scotland, Ireland, Cornwall, and Brittany; corresponded with Ray, Sloane, etc. In 1699 he published 'Lithophylacii Britannici Ichnographia,' a catalogue of 1766 fossils in the Ashmolean. A new edition, with his 'Prælectio de Stellis Marinis Oceani Britannici, et Asteriarum, Entrochorum, et Encrinorum Origine,' was issued in 1760. Among his papers in the 'Philosophical Transactions' are the following:—(1.) 'An Account of the *Lapis Amianthus*, or *Linum Fossile Asbestinum*, found in the Northern part of *Anglesey*; with Mr. Llhwyd's Method of making it into Paper.' No. 166, Vol. xiv, p. 223. (2.) No. 200, Vol. xvii, p. 746. A Latin description of *Siliquastra*, *Bufonites*, *Glossopetræ*, and other fossils, with Figures. (3.) 'On the Difference between the Fossils of *Essex*, and those of *Wales* and *Ireland*; in the former *calcareous*, and in the latter *crystalline*.' No. 291, Vol. xxiv, p. 1566. (4.) 'On the Fossils and Iron Mines of *Brecknockshire*.' No. 334, Vol. xxvii, p. 467. (5.) 'Basalts on the Top of *Cader Idris*.' No. 335, Vol. xxvii, p. 503. (6.) 'Fossils and Antiquities in Wales.' No. 337, Vol. xxvii, p. 93.

Pulteney, 'Sketches of the Progress of Botany,' Vol. ii, pp. 110-116. Wood, 'Athen. Oxon.,' ii, 1,094.—[Ed.]

years ago, when she shook off Ireland, and was herself shaken off by the continent.

I will now proceed to read some extracts bearing upon geology. Shakespeare, in 2 *King Henry IV.*, Act iii, Scene 2, writes :—

> " Oh ! heav'n, that one might read the book of fate
> And see the revolution of the times
> Make mountains level, and the continent,
> Weary of solid firmness, melt itself
> Into the sea ; and, other times, to see
> The beachy girdle of the ocean
> Too wide for Neptune's hips."

In *Hamlet*, Act iv, Scene 9, we have the allusion :—

> " Like the spring that turneth wood to stone."

And in *As You Like It* Rosalind says :—

> " This poor world is almost 6,000 years old."

In the Annual Register, for 1758, we have an account of the natural history of Hartz Forest, by H. Ebrens, M.D., in which it is stated that in a cavern at Scharzfeld they find a quantity of human bones, some of a gigantic size; also the fosile unicorn, of which the peasants had taken much, and sold to the druggists. It is of different shapes, like straight horn, shoulder-blade, rib, tooth, etc. Some say they are real bones, others that they are "lusus naturæ," for were they real, then "cornua ammonis" and other figures on slate would be real, which are now allowed on all hands to be stones of a peculiar kind.

Dr. Ebrens goes on to add that Otto de Querick,* in his 'Experimenta Magdeburgica,' 1672, says that "anno 1663, in a lime-pit near Quedlinburg was found the entire skeleton of a unicorn, which had fixed to its forehead a long bone, or horn, as thick as a man's thigh bone ; " and that the " Theatrum Europœum " mentions that in 1645 the Swedes dug up at Crems, in Austria, a giant's skeleton. The head was as big as a table, a tooth $5\frac{1}{2}$ lbs., and bone of arm as big as a man's body. Dr. Ebrens thinks they may have increased underground, for if the head and tooth belonged to a regularly-proportioned man the giant must have been 176

* Otto von Guericke, born at Magdeburg, 20 November, 1602, died at Hamburg, 11 May, 1686. He studied at Leipsic, Helmstadt, Jena, and Leyden, visited France and England, became engineer-in-chief at Erfurt, and mayor of his native city. He invented the air-pump, 1650.—[Ed.]

times the size of an ordinary man. Dr. Ebrens tells us that the bone is introduced into Materia Medica. It "absorbs, adstringes, and promotes perspiration."

In the volume for 1760 is an account, by an anonymous writer, of Limestone Quarries at Enderteel, near Kirkaldy, in Fife; 200 feet high; a mile from the sea.

The flakes of stone lie horizontally dipping towards the sea, and present, when broken, petrified sea bodies, fish, shells, sea-weed, etc. This rock, in the writer's opinion, proves beyond dispute the vegetation of stone, and the gradual retreat of the sea since the deluge. The author attributes the rocks being inland to the violent flux and reflux of the tide, which heaps them ashore, and gives them the dip; and he attributes the rising of the land from the sea to the vegetation of stone.

John Hutchinson, born at Spennithorne, near Medlam, Yorks, in 1674, about the year 1706 made a large and noble collection of fossils, which came into the possession of Dr. Woodward,* who bequeathed them to the University of Cambridge. The object of the collection was to prove the Mosaic account of creation, and the subsequent deluge. In 1724 he published his 'Moses's Principia,' in which he ridiculed Dr. Woodward's 'Natural History of the Earth,' and his settlement of shells and strata by the laws of gravity.†

In the volume for 1767, we learn that in a cavern discovered at

* John Woodward, born in Derbyshire, 1, May, 1665, died at Gresham College, 25 April, 1728, and is buried in Westminster Abbey. He became Professor of Medicine at Gresham College 1692, F.R.S. 1693, M.D. Cantuar, 1695, and Cambridge 1696, and F.R.C.P. 1702. His 'Essay towards a Natural History of the Earth' appeared in 1695, and his 'Attempt towards a Natural History of the Fossils of England' in 1729. He bequeathed his collection to the University of Cambridge.—[ED.]

† Hutchinson died in 1737. His works secured oblivion by his attacks on Newton's law of gravitation as atheistic. Among his most distinguished followers were Bishop Horne, of Norwich, and Jones, of Nayland. The baselessness of Woodward's theory of fossil deposition was shown by Martin Lister, Ray, Arbuthnot, Tancred Robinson, and others. (See especially Ray's 'Three Physico-theological Discourses concerning the Primitive Chaos and Creation, the Deluge and the Dissolution of the World,' 1692, ed. 2, 1693, ed. 3, 1713.) In this connection reference may be made to a work by Ray's pupil and literary executor, Dale:—'The History and Antiquities of Harwich and Dovercourt, in the County of Essex, by Silas Taylor, gent.; to which is added a large Appendix, containing the Natural History of the Sea-coast and Country about Harwich, particularly the Cliff, the Fossils, Plants, Trees, Birds, and Fishes, etc., by Samuel Dale,' 1730. Dale dwells at length upon the cliff, "whose imbedded Fossils," he says, "I had there discovered; the first Invention of which the late Dr. Woodward in publick

Aix bones are found. Some say human, others that they are ribs of fish. Dr. Wm. Hunter, M.D.,* says when it was decided that the bones belonged to an animal, a dispute arose as to what animal. The inhabitants of Siberia believed them to be those of mammoth, an animal of which they told strange stories, but modern philosophers have held the Mammoth to be as fabulous as the Centaur.

In the volume for 1778, it is mentioned that the Abbé Fortis,† in his 'Travels in Dalmatia,' writes upon a find of immense quantities of bones in caves along the coast, mixed with chips of marble, and also in the islands of Cherso and Osero. They were covered with stalactite three or four inches thick.

In the volume for 1779 a passage is quoted from Whitehurst‡ accounting for mountains and fossils on them in the midst of continents by one great explosion after the strata were laid equally down. This accounts also for the depths of the sea.

In the volume for 1780 Professor Bergman, § writing to Dr. Troil on Basaltic Pillars, is quoted as attributing them to subterranean fires, in preference to crystallization and precipitation, and to the mass contracting after cooling.

In the volume for 1795 is an account of 'Beaumont's Travels through the Maritime Alps.' He considers that the waters covered

company attributed to me." He describes cement-stones "copperas-stones," *i.e.*, pyrites nodules, amber, "selenites," "a congeries of Vermiculi," a "Patella," twenty "Cochleata," or univalves, eighteen bivalves, "Odontopetra," or shark's-teeth, and a vertebrate "ileum;" and gives a plate representing the Crag resting upon the London Clay, and then forming an overhanging cliff.—[Ed.]

* William Hunter, elder brother of the great comparative anatomist, John Hunter, was born at East Kilbride, Lanark, May 23, 1718, and died in London, 30 March, 1783. He was celebrated as a surgeon and as a teacher of anatomy, and collected the museum now in the University of Glasgow.—[Ed.]

† The Abbé Jean Baptiste Albert Fortis was born at Vicenza in 1740, and died at Bologna, 21 October, 1803. His 'Travels in Dalmatia' were first published in 1774; but the English translation of 1778 has many additions. Amongst various other works he published a 'Voyage minéralogique dans la Calabre,' 1786-7; a Letter 'su i pesci fossili del monte Bolca;' and 'Mémoires pour servir à l'histoire naturelle et principalement à l'oryctographie de l'Italie,' 1802.—[Ed.]

‡ John Whitehurst was born at Congleton, 10th April, 1713, and died in Bolt Court, Fleet Street, 18th February, 1788. He was brought up in his father's trade, that of a watchmaker. In 1778 he published his "Inquiry into the original State and Formation of the Earth," the work quoted in the 'Annual Register.' In 1779 he was elected a Fellow of the Royal Society. Chalmers.—[Ed.]

§ Torbern Bergman was born March 20th, 1735, at Catharineberg, Westgothland, and died July 8th, 1784. A pupil of Linnæus, he became Professor of Chemistry and Mineralogy at Upsala. Chalmers.—[Ed.]

these mountains in the first formation of continents, and drove the huge masses of granite to the tops of the hills, where they are now found. Here we find primary, secondary, and tertiary rocks mentioned.

In the volume for 1796, Prof. Martyn* describes the digging of a well at Little Dalby, where Stilton cheese was first made in 1730. At a depth of 10 feet were frequent nodules of chalk, and the clay was full of small selenites; at 30 feet full of pectens, and ammonites of different species, gryphites, and nodules of ludus helmontii.

In the same volume mention is made of a treatise 'On a Submarine Forest, East Coast of England,' by Joseph Correa de Serra, LL.D.,† etc. At Sutton, Lincolnshire, by means of a boat, he set foot on one of the largest islets appearing (30 yards long, and 25 wide, the tide being at its lowest). The coast then had plenty of those islets. The remains of some of the trees were still standing on their roots, the bark and roots appearing as fresh as when growing. The islets extended 12 miles in length by one in breadth. He finds this forest extends inland under 16 feet of clay. He gives the cause of the vegetation that had COLLECTED to subsidence, and to its having been brought together by the agency of ancient rivers, as the Mississippi acts now; and points to the difference between this vegetation and that found in coal fields. Of subsidence, he says, old men at Thorne affirm that whereas they before could see little of the steeple of Goole, they now see the churchyard wall. The author remarks of the forest that it is of very ancient date, but the denudation that laid part of it bare is recent.

Cowper, in *The Task*, about 1783, writes:—

> "Some drill and bore
> The solid earth, and from the strata there
> Extract a register, by which we learn
> That he who made it, and revealed its date
> To Moses, was mistaken in its age."

* Thomas Martyn, Professor of Botany at Cambridge 1762-1825, son of John Martyn, also Professor, was born at Chelsea, 1735, and died at Pertenhall, Cambridge, 3 June, 1825. He wrote numerous botanical works. Gorham, 'Memoirs of John and Thomas Martyn,' 1830.—[ED.]

† The Abbé Joseph Correa de Serra, Secretary to the Academy of Sciences, Lisbon, having befriended the French botanist, Broussonet, in Portugal in 1794, found it necessary to flee to England, where he took refuge with Sir J. E. Smith, in Great Marlborough Street. He was afterwards sent as Portuguese plenipotentiary to Washington, and, in 1821, as minister of science and art to Brazil. He died in Lisbon in 1823. 'Memoir and Correspondence of Sir J. E. Smith.'—[ED.]

The following passage from Sir Walter Scott's *St. Ronan's Well*, written in 1832, Chap. II., is familiar to most people.

Meg Dodds, *loq*: "And me leddy, ye ken, has wit at wull, and has a' the wise folks out from Edinburgh at her house at Windwa's yonder, which it is her leddyship's will and pleasure to call Aircastle; and they have a' their different turns; and some can clink verses wi' their tale as weel as Rob Burns or Allan Ramsay. And some rin up hill and down dale, knapping the chucky-stanes to pieces wi' hammers like sae mony road-makers run daft. They say it is to see how the warld was made."

Wordsworth, also in the present century, writes:—

"You may trace him oft
By scars which his activity has left
Beside our road and pathways, though, thank Heaven!
This covert nook reports not of his hand.
He who with pocket-hammer smites the edge
Of luckless rocks, or prominent stone, disguised
In weather-stains, or crusted o'er by nature
With her first growths, detailing by the stroke
A chip or splinter, to resolve his doubt;
And, with that ready answer satisfied,
The substance classes by some barbarous name
And hurries on; or from the fragment picks
His specimen, if but haply interveined
With sparkling mineral, or should crystal cube
Lurk in its cells, and thinks himself enriched,
Wealthier, and doubtless wiser than before."

In conclusion, I may remark that the finding of huge bones has for ages given rise to much fabulous matter. "There were giants in those days;" and we have seen that the inhabitants of Siberia told strange tales of the Mammoth, and over China, Japan, and India there are images and designs of giants, dragons, griffins, and serpents with enormous heads, which I cannot but think owe their origin to the finding in olden times of large and mysterious fossil bones, and skulls.*

* Reference is made to various other interesting early works, papers, and incidental allusions bearing on geology in the copious bibliographies affixed to some of the Survey Memoirs, notably Mr. Whitaker's on the London Basin and Mr. Topley's on the Weald.—[Ed.]

Notes on the Artificial Unmaking of Flints.

By T. Hay Wilson.

(Read June 7th, 1889.)

Reading Professor Judd's interesting paper on "The Unmaking of Flints,"* which I was not fortunate enough to hear, it occurred to me that as this same "unmaking" has often been a source of great trouble and anxiety to me, a few notes of my special experience of an artificial unmaking may be of interest.

This experience lies in the behaviour of Flint Shingle when exposed to the action of hot gases, and the following destructive agents: percussion, attrition, heat, with pressure, moisture, and acid.

The gases are the products of combustion discharged from the cylinder of a gas-engine, where, in a few cases, it has been essential, from surrounding circumstances, to have the slight noise from the exhaust completely silenced. The working parts of a gas-engine are very similar to those of the ordinary steam-engine, the reciprocating motion of a piston being caused by impulses from the explosion and expansion of a combustible mixture of gas and air, in a cylinder, instead of by the expansion of steam. After the explosion of gas and air, the piston is driven forward, and the products are expelled during the return stroke of the piston, and (in these special cases) driven through a chamber filled with shingle, to reduce the pressure and quiet the noise. These chambers are sometimes made in the ground near the engine, and are about 6ft. deep and 3ft. square, built with fire-brick, and nearly filled with shingle. The hot gases, in some of these cases amounting to about 7,000 cubic feet per hour, are passed through the shingle, entering at the bottom with a pressure of about $2\frac{1}{2}$ atmospheres and a temperature of nearly 1,000° Fahrenheit, and escaping quietly through a ventilating pipe at the top, an iron plate being firmly fastened down to the brickwork, with an asbestos joint to prevent the gases from leaking into the air except through the ventilating pipe.

The constituents of the gases are—air, nitrogen, carbonic acid,

* 'Proc. Geol. Assoc.,' x, 217.

and aqueous vapour; the acid being about 8 to 10 per cent. of the weight and the H_2O about the same. Taking the specific heat of silica at say 0·2, enough heat is furnished by the combustion of 100 cubic feet of the live gas to raise the temperature of 5,000 lbs. of shingle about 15° F. Of course some of this heat is absorbed by and conducted through the walls of the chamber into the adjacent ground, a little is lost by radiation from the plate, and more goes into the atmosphere through the ventilating pipe.

The hot gases being continually poured through the chamber, in some cases for 10 to 12 hours per diem, the temperature would be very great, were it not for the aforesaid cooling agencies; as it is, the temperature of glowing cast-iron is sometimes reached, and probably the centre of the mass is for some time daily not less than 1,400° F., or possibly more.

A recent test by the Society of Arts gave the temperature of the products before leaving the cylinder at over 2,000° F.

Percussion is caused not only by the entrance of the gaseous products at a pressure of about 35 lbs. per square inch, but by their hammering the stones against each other. Occasionally explosions occur in the inlet pipe, which for the moment enormously increase the pressure and also the temperature.

Attrition is one of the chief sources of destruction to the shingle, the mass being moved by each influx of gas, these influxes being sometimes 80 or more per minute.

Moisture.—While the gas is passing, the temperature is, of course, too great to allow of condensation; but for 12 or 14 hours of the 24, and for about 40 hours at the end of a week, the cooling influences alone are at work, and condensation often takes place. Moreover, a leakage often occurs through the walls of the pit, which becomes open and is destroyed by the expansion and contraction.

Acid.—Flint is the only shingle I can find to stand this action for any length of time, and I always test a sample with dilute sulphuric acid before filling a chamber. I have known cases where limestone has got amongst other shingle, and it is acted upon as if in a mill. In one case in particular, at Oxford, three days after a chamber was started, I found over two tons had almost disappeared, as a fine powder, and had been deposited over the adjacent roofs. The chamber was refilled with

good flint shingle, and has not been touched for about three years, the shingle having stood the daily influence of about 40,000 to 50,000 feet of gaseous products, without serious disintegration. This is the most successful case I know with this kind of chamber.

Pressure is considerable at all times when the gases are passing, and may be as much as 200 lbs. per square inch, when explosions occur. The shingle which appears to stand best is that composed of well-worn beach or river-gravel flint pebbles (Shown in sample 3). I am informed by the contractor that all those samples which I have recently found to last fairly well, are dredged between Gravesend and Sheerness.

The samples exhibited are of this sort. I do not know where the Oxford shingle was procured, though probably it was from the gravel on which the city stands. In the Report of the Excursion of the Association to Oxford in 1874 ('Proc. Geol. Assoc.,' Vol. iv, p. 91), Prof. Phillips thus describes the gravel overlying Oxford Clay, on which the city stands:—

"In composition it is mostly Oolitic, but with some admixture of materials from the high-level gravel, which is often found capping the plateaux of the district. These materials are chiefly quartzites, felstones, and grits; flints are also found."

SAMPLES.

No. 1.—This shows the original and disintegrated flint also; the test having been very severe, as from the nature of the ground (near Wallbrook) a brick pit could not be made, and an old boiler-end about 6ft. long formed the receptacle. The internal pipes show signs of heat-action, due to very high temperatures only. The disintegrated portion is from the bottom where the gases enter. This has been down twelve months, and about 30,000 cubic feet of gas passed through daily on week-days.

No. 2.—From same chamber, previously opened, had been in for about six months: the bulk was badly destroyed.

No. 3.—From a brick chamber with frequently up to 80,000 feet per diem of products passed through, and subjected to severe explosions; most of the bulk quite disintegrated. The undamaged portion will stand anything as far as I can test it.

No. 4.—Small shingle (I believe from St. Leonards). This was closely packed in a small iron vertical chamber, and gases

passed through from above: after about six years it has not wasted appreciably. This chamber has cool air occasionally passed through, say 10 or 15 times per minute.

In some instances, where space is available, it is not necessary to cover the top, and the shingle is merely heaped up, the vapour flying about; in such cases the temperature is much lower, as radiation is considerable, and gases escape freely. In many cases the small cylindrical iron chamber just named (No. 4) is used instead of the pit, and closely packed with fine shingle, being placed vertically in the exhaust pipe, and the gases entering at the top, the grinding action does not occur, as the mass is not lifted, and shingle in these lasts for years with scarcely any waste. Iron chambers like this are known as "Justice's" patent, and have been largely used; the heat passes through them much more quickly, and there is considerably more radiation in proportion.

It seems to me that percussion and attrition have been, in all these cases but the Oxford one, the most troublesome agents of destruction, as the action of the acid appears to be successfully resisted by the specimens I have shown you.

It seems further clear that flint ultimately becomes reduced to mud, not sand.

Description of Specimens Named.

Nos. 1 and 2 showed pieces of Flint-shingle of the normal size used, varying from an equivalent of, say, 1½ inch cube to the size of a walnut, more or less water-worn and rounded; also a disintegrated portion reduced to about the size of hazel-nuts, partly flaked and split, varying in size down to powder.

No. 3 showed some completely rounded pieces of same shingle showing no reduction, and some ordinary less-worn Chalk-flints, burnt red and brittle, flaked, and disintegrated, as in Nos. 1 and 2.

No. 4.—Small shingle, about $\frac{3}{16}$ inch cube, showing no reduction from normal bulk; gases having entered at top of shingle column the mass was not shaken up.

Other similar specimens not named in these notes were also shown.

The Geology of Upton and Chilton, in Berks.

By A. J. Jukes-Browne, B.A., F.G.S.

(Read June 7th, 1889.)

Part I. Cretaceous Rocks.

This paper is intended as explanatory of a section through the Chalk and Upper Greensand escarpments from Chilton Downs to Didcot, and as a guide to the cuttings and exposures of the Chalk near the villages of Chilton and Upton, a district which will probably be visited by the Members of the Geologists' Association during the summer.

I propose to give a brief description of each of the divisions of the Upper Cretaceous series which will be shown on the new edition of the Geological Survey Map, and to mention the exposures which occur in each division within easy reach from the stations on the Didcot and Newbury line.*

Gault.—The marly clays of the Upper Gault are exposed in the railway-cutting north-west of Didcot. The lowest beds seen are grey argillaceous marls, with *Avicula gryphæoides*. These pass up into more shaly micaceous marls with the same fossil and small scattered phosphatic nodules. These beds were included in the Upper Greensand on the old edition of the map, but the base of this is now taken where the first layers of Malmstone occur.

The Gault at Didcot is more than 200 feet thick, for a well at one of the hotels near the station was bored to a depth of 208 feet, passing through clay into rock and sand, and the site of this must be 30 or 40 feet below the line which is taken as the base of the Malmstone.

Malmstone.—The Malmstone of Berks closely resembles that of Surrey and Hants. It is a light grey calcareo-siliceous stone, which lies in layers, separated by bands and seams of soft micaceous marl. In the lower part the stone beds come in as courses in the marl, but in the higher part the beds are thick, with only thin partings of marl. Much of the rock is very siliceous, the silica consisting partly of the spicules of

* The information was obtained during the official survey of the district, and is published by permission of the Director-General of the Geological Survey.

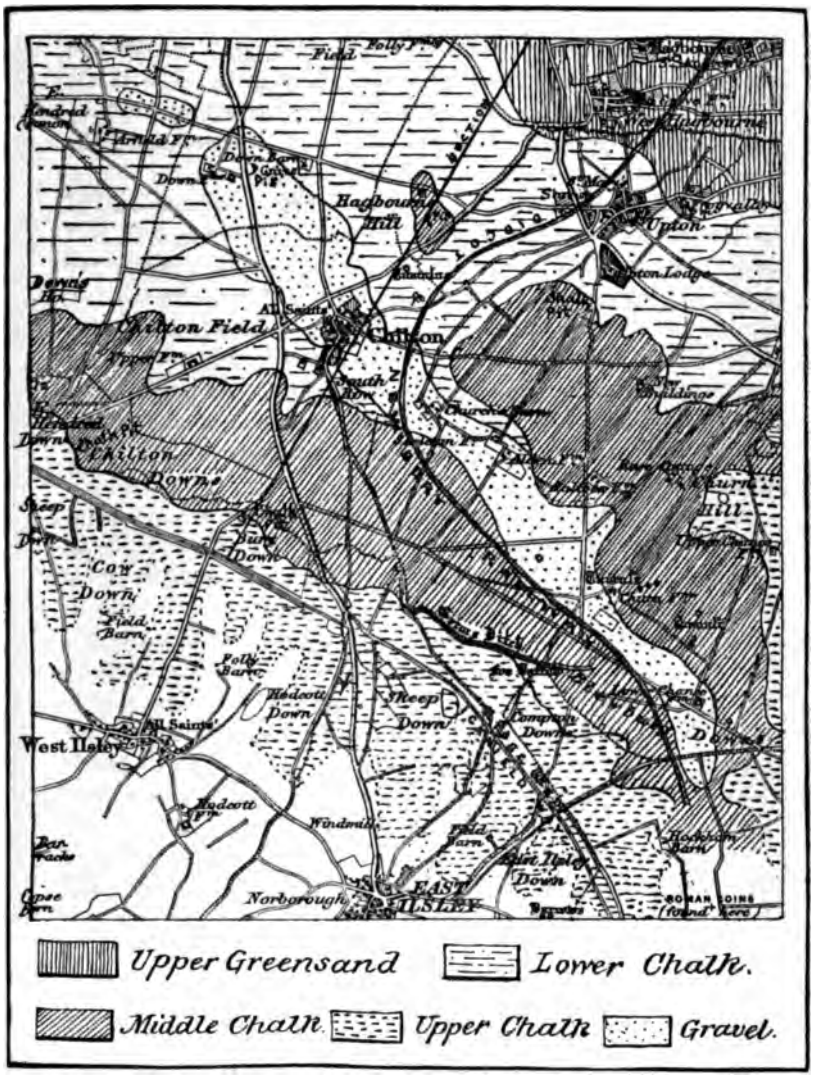


FIG. 1.—New (unpublished) Geological Survey Map of the district around Chilton, by A. J. JUKES-BROWNE. Contributed by the kind permission of the Director-General. (Scale 1 mile to 1 inch).

siliceous sponges and partly of minute discs and globules of colloid silica, which seem in some way to have been derived from the decomposition of the spicules.* Spangles of mica and small grains of glauconite are also abundant in it. The thickness of this Malmstone division of the Upper Greensand is very considerable—probably about 80 feet—and it occupies all the ground between Didcot and West Hagbourne.

The first shallow cutting on the Newbury line south-east of Didcot shows a few feet of tough grey marl overlying a floor of Malmstone, and the next cutting (beyond a bridge) shows the same grey marl, here very wet, overlain by Malmstone in alternating courses of harder and softer stone. These beds may be followed through the cutting, and have a gentle dip to the southward. Few fossils, except an occasional *Avicula gryphæoides*, are to be found, but those who have microscopes should not neglect to take a sample of the Malmstone, from which a slide should be cut.

Glauconitic Sand.—This division forms a narrow band below the Chalk Marl, its thickness between Harwell and Upton being only about 12 or 14 feet, so that its stratigraphical importance is small, and much less than is represented in Prof. Prestwich's section ('Q. J. G. S.,' Vol. xxxviii, p. 128). It is a soft green sand, consisting of a mixture of glauconitic grains and fine quartz sand, with a further admixture of calcareous matter in the upper part, passing upward into a glauconitic marl, with fossils in phosphate of lime. This is the so-called Chloritic Marl, and in this district there is no line of erosion, but a complete passage from the Greensand into the Chalk Marl.

The glauconitic sand and marl crop out just to the south of West Hagbourne, and cross the main road by the old turnpike, but no good exposure of them occurs for several miles either eastward or westward.

Lower Chalk.—This division of the Chalk here attains a great thickness, and presents some features which are not found further north. The thickness is estimated at 220 feet, and it is divisible into two parts, which are separated by a thin representative of the Totternhoe Stone. The lower zone (that of *Ammonites varians*) corresponds with the Chalk Marl,

* See paper on "Colloid Silica in the Lower Chalk," by the author and W. Hill, F.G.S., in the 'Quart. Journ. Geol. Soc.,' Vol. xlv (1889), p. 403.

though most of it here is firm-bedded chalk. The higher zone is that of *Holaster subglobosus*, and is limited by having the Totternhoe Stone at its base, and the marls of the *Belemnitella plena* zone at its summit. The zone of *Ammonites varians* is about 140 feet thick, and the upper two zones are about 80 feet.

The first point of notice is the breaking out of strong springs near the base of the Chalk to the north and east of Upton. Upton Station stands about 60 feet above the base of the Chalk, the well there being 52 feet deep, with hard chalk at the bottom.

The first cutting on the line south-west of Upton is in firm marly chalk, with *Ammonites varians*, etc., having an undulatory dip to the southward.

The next cutting is just half-way between Upton and Chilton. Near the centre it is about 30 feet deep, the lower 20 feet consisting of blocky and marly chalk, with many fossils. Near the top, by the bridge, two hard beds are seen, which are probably the same as those found at the base of the next cutting.

The third cutting is only separated from the second by a narrow valley, and commences about half-a-mile east of Chilton Church. It shows an interesting section, including beds of siliceous chalk, soft marl, Totternhoe Stone, and grey chalk, the last cut off by a mass of Post-Tertiary loam, which sweeps down nearly to the bottom of the cutting and continues for a distance of more than half-a-mile.

At the northern end of this cutting the following beds are seen:—

	Ft.	In.
Chalk, broken and talused	15	0
Soft grey marl	5	0
Hard compact siliceous limestone	1	3
Soft shaly chalk	0	6
Hard grey siliceous chalk	0	9
Loose grey marly chalk	3	0
Hard rough grey chalk...	0	6
Loose grey marly chalk	2	0
Rather hard blocky chalk, seen for	3	0
	31	0

All the hard beds here seen contain globular colloid silica, sponge-spicules, and small grains of glauconite. They weather

out as conspicuous courses, and the highest is so hard as to ring when struck with a hammer. Many fossils may be collected. The beds dip gently to the S.S.W. for a little distance, and then suddenly bend down in the same direction at an angle of four or five degrees, bringing the higher beds within reach of measurement. A section taken between this point and the bridge shows:—

	Feet.
Grey chalk in thin beds	12
Hard grey rocky chalk	1
Hard grey chalk in thin beds, with partings of marly chalk	5
Totternhoe Stone—dark brownish-grey stone with phosphatic nodules, about	2
Soft grey marl (as seen before)	5
	25

The Totternhoe Stone varies from one and a half to two feet, and indeed there is no definite upper limit, the lines of curvilinear jointing passing through it and the overlying grey chalk, and giving a false appearance of oblique current-bedding in some places. Fossils are abundant in the stone, and *Holaster subglobosus* may be found in the grey chalk above, but no specimen was found in that below the Totternhoe Stone, nor has this urchin been found anywhere below that horizon except in Norfolk and Lincolnshire.

The highest part of the Lower Chalk is not exposed in the railway-cutting, but may be seen in a quarry on Hagbourne Hill, north-east of Chilton. This hill is capped by outlier of Melbourn rock, the base of which is seen in the pits; the section showing:—

	Ft.	In.
Soil and rubble	1	0
Melbourn Rock—hard nodular white chalk, with partings of greenish marl between the courses	4	0
Soft buff-coloured marl, with *Rhynchonella cuvieri*	0	6
Hard white compact chalk, with *Rhynchonella plicatilis*, *Ostrea vesicularis*, etc. ...	1	0
Grey laminated chalk passing down into the massive white chalk	3	0

The zone of *Belemnitella plena* is here unusually thin, and the lower marl band is hardly separable from the underlying chalk.

Middle Chalk.—This division is based on the Melbourn rock, and exhibits the usual succession of zones, viz., (1) zone of *Rhynchonella cuvieri*; (2) zone of *Terebratulina gracilis*; (3) zone of *Holaster planus*, in which the Chalk Rock may, for the sake of convenience, be included, though it is at present uncertain whether this rock has most claim to be regarded as the top of the Middle Chalk or as the base of the Upper Chalk.

It is noteworthy that the Middle Chalk throughout Berkshire is comparatively thin, only 150 feet, or about two-thirds of the thickness it attains in Kent and in the counties north of the Thames Valley. In this connection it is well to remember that the thicknesses above given for the Lower and Middle Chalk in Berkshire are almost exactly the same as those assigned to these divisions in the deep boring at Richmond;* we may, therefore, conclude that the Berkshire facies of the Chalk is continued westward beneath Richmond and the south of London.

The Melbourn Rock crops out at the south-eastern end of the long Chilton cutting; but it is in a broken condition, apparently cut up by numerous small slips and faults. It passes up into hard lumpy chalk, which is full of fragments of *Inoceramus mytiloides*, and in this, just before reaching the level crossing, a band of hard, yellowish rock rises up from the level of the rails; in and below this *Echinocorus subrotundus* may be found.

A good section of the basal part of the Middle Chalk is exposed in the quarry on the hill south of Upton Lodge (east of the railway).

Part of the next zone (*Terebratulina gracilis*) is exposed in a quarry on the slope nearly a mile and a half east-south-east of Chilton, and consists of firm white chalk without flints. It lies in thick beds, and is elsewhere dug for the manufacture of whiting.

The Chalk Rock is exposed in a pit on the hill about 50 feet above the last-mentioned quarry, and still better in several quarries on the Hendred Downs to the westward. The fine collection of Chalk Rock fossils now in the Woodwardian Museum, Cambridge, came from these pits (near Cockhamsley Knob). Chalk Rock has also been dug on Bury Downs, about a mile south-west of Chilton.

* See 'Quart. Journ. Geol. Soc.,' Vol. xl, p. 705 *et seq.*

Upper Chalk.—This is no longer synonymous with the "Chalk with flints," because flints are abundant in some parts of the Middle Chalk, especially in the more northern counties. The lowest zone of the Upper Chalk is that of *Micraster cor-testudinarium*, and some 13 feet of this are seen in the pit on Bury Down, where it includes a grey band which contains many Ventriculites.

Higher beds may be seen in a pit on the road to East Ilsley; but only a small thickness of the Upper Chalk occurs on the Ridgeway, for the dip is so slight that all the valleys on its southern side are cut through the Chalk Rock into the Middle Rock, and the winding outcrop of this rock will be a very noticeable feature on the new edition of the Survey map.

Part II. Drift Deposits.

These were described by Prof. Prestwich in 1882,* and except as regards the spread and extent of the deposit, I have little to add to his account; the chief section, indeed, not being now so clear or so accessible as it was when he visited the cutting.

The chalky marl and rubble which is banked against the Chalk in the second cutting on the line appears to me to be rainwash, or the "run of the hill," and to be of a later date than the mass of gravel and loam in the Chilton cutting.

The chief gravelly deposit here sets in about 150 yards north of the bridge which crosses the line nearly due east of Chilton. It is here a yellowish gravel, consisting of angular flints and chalk rubble in irregularly stratified beds, with occasional layers of brown loam. This continues, with a depth of from 12 to 16 feet, for about 500 yards, and then thickens, its base descending gradually below the level of the line, though the cutting remains about 30 feet deep.

At the northern end of the deposit, and near its base, numerous Mammalian remains were found, chiefly teeth and broken bones, belonging to the following creatures:—

Elephas primigenius.
Rhinoceros tichorhinus.
Bison priscus (?).
Cervus tarandus.
Cervus sp.
Equus caballus.

* 'Quart. Journ. Geol. Soc.,' Vol. xxxviii, p. 127.

Near the second bridge (west of Church's barn) there is a deposit of white and buff marly loam, which contains shells. The following mollusca were found here by Prof. Prestwich :—

Pupa marginata (abundant).
Helix hispida (common).
Limax agrestis (one specimen).
Succinea oblonga (a few).
Limnæa truncatula (rare).
Planorbis albus (one specimen).

It will be noticed that the larger number of these are land shells, though the *Limnæa* and *Planorbis* are sufficient to prove the presence of water. The matrix is a chalky paste, containing a certain amount of fine sand as well as pellets of chalk, and is clearly an ancient wash from the soil of the neighbouring hills.

With regard to the coarser parts of the deposit, Prof. Prestwich remarks that "the fragments of chalk vary from the size of a pea to that of a bean. Some, which consist of soft chalk, are worn and rounded, but others, which consist of a very hard chalk [? Chalk Rock], are flat and subangular. . . . All the fragments of flint, on the other hand, even the smallest, are perfectly sharp and angular, and are generally not discoloured. Some, however, are slightly whitened. The chalk *débris* predominates at the north end of the cutting, and the flint *débris* at the south end." He also found a few blocks of very hard and compact Sarsenstone at several places in the lower part of the deposit. So far as can be seen in the railway-cutting, the deposit might be a purely local one of small area, filling up a hollow in the surface of the Chalk. Prof. Prestwich noticed that it spread north-westward through Chilton and for some distance toward Hendred; but he does not seem to have tried to trace its extension in the opposite direction. He says "it appears to fill hollows on this elevated chalk-plain in a manner rather difficult to account for," and he points out that the hollows may have been originally deep, dry combes, such as are so common everywhere among chalk hills.

While surveying the Chalk of this district I took the opportunity of tracing the limits of this peculiar Drift so far as I was able, and thus ascertained some interesting facts with regard to the lie and extent of the deposit.

Loamy and gravelly material underlies nearly the whole of Chilton, and it is important to observe that the valley of the watercourse which traverses the village cuts right across the trend of the older deposit, and proves that a new minor system of drainage has been developed since the formation of the old gravel and loam. This watercourse runs from south-west to north-east, and cuts through the escarpment of the Lower Chalk at Upton, whereas the tract of gravel runs from north-west to south-east, and partly in a valley which opens southward through the escarpment of the Upper Chalk.

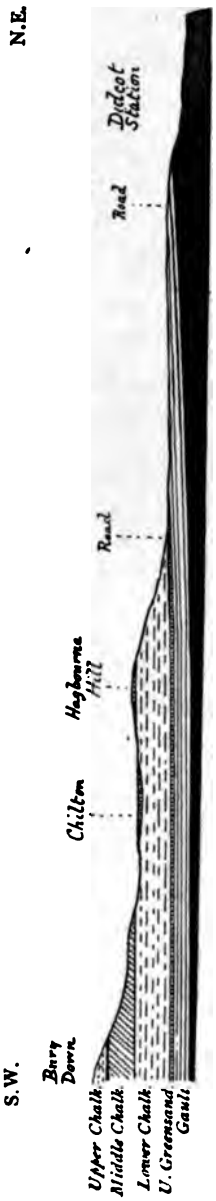


FIG. 2.—Section through Chilton and Didcot. (A. J. JUKES-BROWNE).
Horizontal scale, mile to 1 inch; vertical scale, 1,200 feet to 1 inch.
N.B.—The patch under "Chilton" is gravel (see map).

The gravel occupies a continuous tract, with an average width of half-a-mile for the distance of more that a mile to the north-west of Chilton, as far as the Down Farm (marked "Barns" on the one-inch map), where chalky gravel has been dug for many years. It is then interrupted; but a small tract of gravelly soil lies on the plateau near Arfield Farm, at a level of about 390 feet, and on the southern side of the deep valley which leads into the "Lydeway," east of Hendred. Here, again, it is quite clear that the old gravel is quite independent of the modern system of drainage, and that it was formed at a period when the physical geography of the district was very different from what it is now.

I may here mention that the levels supplied to Prof. Prestwich

by the local engineer were not accurate. The level near Arfield (390 feet) is the highest to which the deposit attains; the level marked on the six-inch Ordnance Map at Chilton Church is 383 feet (not 407), and the surface levels by Church's Barn and Alden Farm vary from 363 to 370. It is clear, therefore, that the plateau occupied by the gravel has a gentle slope from north-west to south-east.

By Alden Farm, which is about a mile south-east of Chilton, there is a gravel-pit showing the same kind of chalky gravel with numerous angular pieces of broken flints. Hence the gravelly soil can be traced to the neighbourhood of Churn Farm, where the surface levels are from 353 to 356 feet. Churn Farm stands at the entrance to the broad valley which curves southward below Compton Downs, and is occupied by a watercourse which eventually drains into the Thames at Pangbourne. I have not myself followed the gravel further than the road which crosses the valley south of Lower Chance Farm, where the height marked in the centre of the valley bottom is 343 feet, but it is probably more or less continuous to and beyond Compton.

Prof. Prestwich is, therefore, barely correct when he says that the gravel does not "follow any river-course;" it does not follow the course of the little streams which now drain the plateau of the Lower Chalk; but it is distinctly a valley gravel, and occupies the upper end of a valley, which still possesses a watercourse. Anyone who is familiar with the physics of chalk streams knows that the level at which the springs break out varies with the rainfall of the season, and as everyone concedes that at the epoch of the older river-gravels the rainfall was probably much greater than the present, we may safely assume that the bournes then broke out at very high levels, and that the chalk valleys were occupied by permanent watercourses for a much greater distance than they are at present.

I must not, however, be understood as suggesting that the deposit in question is a river-gravel; I quite agree with Prof. Prestwich in thinking that the presence of broken, unworn flints is incompatible with prolonged water-action, and also that the deposit is different from ordinary late Post-Glacial rain-wash. The broken and unweathered flint fragments suggest the action of frost and snow, while the shells and mammalian

remains show at the same time that the climate could not have been very rigorous. I think, however, that it is a deposit which might be formed at the upper end of a Chalk valley during an epoch when the average rainfall was greater than it is now, and when a lower winter temperature permitted a large amount of snow to accumulate on the Chalk Downs. Rain-wash formed under such conditions would necessarily be more bulky, more rapidly accumulated, and composed of coarser materials than that formed in more recent times.

It need not surprise us to find that the upper part of this ancient rain-wash no longer lies within a valley. It is clear that the escarpment of the Lower Chalk has been greatly modified since the formation of this gravelly material; this alteration is largely due to the recession of the numerous spring-heads which issue from the lower slopes of the escarpment, and partly, no doubt, to the general degradation of the surface by rain; the result being that the drainage of the country round Chilton, which was formerly directed into the Compton Valley, is now taken off by watercourses which flow northwards and trench the escarpment of the Lower Chalk.

Neither need we go to the sea-coast at Brighton and Sangatte to seek for similar deposits, for gravels that are analogous in every respect occur in the upper part of every valley which breaches the escarpment of the Chalk in the counties of Buckingham, Hertford, and Bedford. There are gravels mainly consisting of broken angular flints on the eastern side of the Thames Valley, east of Wallingford and below the Chalk escarpment, at a level of about 400 feet; the lie of these gravels and their relation to the short combe-like valleys above them making it clear that they have been brought down by rushes of water from these combes, and have been spread out on the lower plateau very much after the fashion of the sub-aërial deltas formed by some of the Himalayan torrents in India.

There is a gravel composed of angular flints in a chalky matrix occupying the floor of the depression at the head of the Wycombe or Loudwater Valley in Bucks. This is now a dry plain opening trumpet-wise between the slopes of the Chalk escarpment, and the gravel now lies partly on the watershed between the Loudwater and the watercourses which run northward to the Thames. As near Chilton, the old gravel is trun-

cated and trenched by the valleys of a newer system of drainage.

At the head of the Misbourn Valley on the watershed above Wendover there is a similar chalky gravel, and it runs southward along the bottom of the valley to the place where the modern watercourse begins near Missenden.

There is a large area of the same kind of gravel with some chalky loam near Tring, at the head of the Bulbourn Valley, lying on a plateau, and in positions to which the materials could not possibly be carried by modern streams or modern rainfalls. Here also a more modern system of drainage has been produced by the recession of spring-heads.

Another good instance of such deposits, more closely resembling in lithological characters the Chilton beds, occurs at the head of the Gaddesden Valley, which is a tributary of the Bulbourn. Here there is not only a large spread of chalky and flinty gravel, but in the village of Dagnal a considerable thickness of stiff, chalky loam similar to that at Chilton.

In all these cases the conditions are analogous to those of Chilton, the deposits occurring at the heads of valleys which appear to have been breached by the action of rain and springs on the outer slope of the Chalk escarpment. When the Members of the Association are at Chilton, let them stand on the bridge which crosses the line east of the village and look northward down the valley through which the railway is carried. They will see that this gap could not have existed at the time when the Chilton gravel was deposited, and that in all probability the Melbourn Rock was then continuous from Upton Down to Hagbourn Hill, and doubtless extended still further to the northwest; while the heights of the Lower Chalk circled round the head of the old valley by Hendred and Arfield.

On the site of Upton gap there was probably a deep combe, opening eastward toward Upton, and having a strong spring which broke out at a higher level than the present one. By the recession of this spring-head, aided by the erosion of a heavy rainfall, the combe was worn back till the ridge behind it was completely breached, and a new system of drainage was formed, passing across the old one, and cutting down to a lower level. There is a similar depression south-west of Blewbury, but not cut quite low enough to change the system of drainage.

On the Estuary of the Thames and its Alluvium.

By F. C. J. Spurrell, F.G.S.

(*Read July 5th, 1889.*)

The estuary of the Thames lies in an old river-valley cut out of Eocene beds and the Chalk. It is bordered at high levels on either side by sheets of gravel, the intervals between which decrease as lower levels are reached. They are left as the result of the denuding action of the older river. These gravels, taken generally from about the contour-line of 300 feet above Ordnance Datum downwards, are of the kind which has received the title of Palæolithic, from the fact that they have embedded in them those types of early stone implements to which Sir J. Lubbock gave that distinguishing name. Yet there are among the lower patches of gravel some in which no extinct remains, nor stone implements have been found which are not clearly *remanié*. One such spread of gravel, which amounts to a distinct terrace, is found on either side of the estuary, between London and Gravesend. It often reaches the elevation of 20 feet, or a little higher above the adjacent marsh, and borders it. This terrace is apparently the result of the violent breaking up of the neighbouring older gravels by frost and floods, and is the direct continuation of the condition of that climate which produced the *Trail* and *Head;* which destruction lasted for so short a time that it did not suffice to imprison a special fauna or type of implement within it, if such existed. These banks of gravel, while covering here and there older gravels containing Palæolithic implements, graduate into a lower layer, which spreads across the whole valley of the Thames at its deepest excavation. This lowest layer of all lies beneath the alluvium, and differs in appearance from the older gravels. It is mostly grey in colour, though there are parts where it is black, a light and even a bright red; the grey and black being the result of deoxidation of the peroxide of iron by the vegetable matter from the overlying alluvium. It often contains incrustations of lime and iron-pyrites on the stones. This gravel presents the usual features of a river deposit, and passes from coarse to fine. It is covered generally with fine sand; and, near the shores, with loamy brickearth, which belongs to the warp produced by floods, constituting altogether a

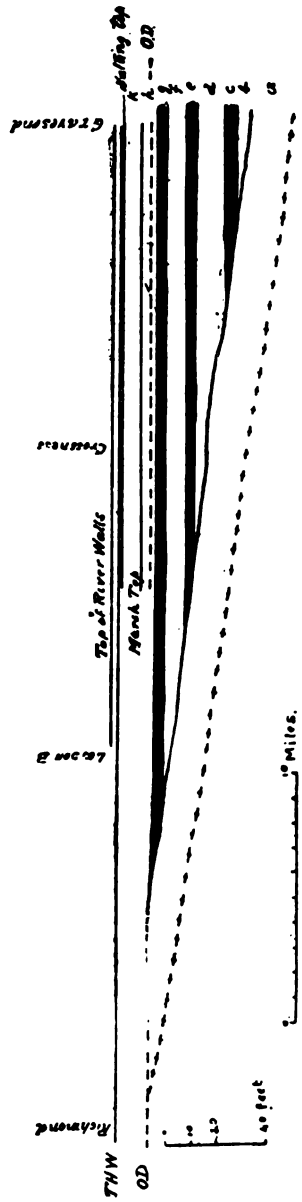


FIG. 1.—Diagram Section along the course of the Thames.

a represents the layer of old river sands and gravels, the upper and lower margins of which are shown.
b is tidal clay with sand.
c, peat.
d, tidal clay.
e, peat.
f, tidal clay.
g, peat, at the upper part of which lie Roman remains.
h, surface clay [tidal] of the marsh.
k, the clay now accumulating to form saltings.

distinct series. The older gravels at high levels do not admit of a satisfactory determination as to the amount of the fall in the river which produced them; but when we have reached the continuous sheet on which the Thames now runs an effort of this kind can be made with success. In the diagram Fig. 1, I have taken a line along the river, from Gravesend, where the Tilbury docks excavation enabled an excellent section across the river-bed to be made, from the lowest part of the gravel-bed there, to the lowest part of the gravel at Pimlico. The diagram shows the contact of the gravel with the older rocks. At Pimlico measurements were obtainable from the Engineer's published account of the foundation of the London, Chatham, and Dover Railway Bridge (Victoria). Intervening measurements have been made from several similar sources, such as the excavations of the late Metropolitan Board of Works, the works of the City of London, particularly those of the new Tower Bridge, and innumerable borings published and unpublished, together with much personal observation of excavations of all kinds. The general thickness of the whole layer of gravel and of the sand which lies conformably upon it along the whole distance is fairly uniform, and is distinctly shown in contrast with the superincumbent alluvium. If the lower plane of the old gravel-bed is carried up-stream it will rise to the Ordnance Datum about Richmond; the upper part of the bed being level with the adjacent shores there. At Gravesend the lower plane is between 60 and 70 feet below O.D.

Notwithstanding that the waterway of the Thames is very irregular, it is clear that it has kept its present line of flow the same, within narrow limits, since it first became estuarine. The same broad masses of silt or marsh have remained, the bends of the stream have impinged on the same "hards," and apparently the same places have, with few exceptions, been the customary crossings or ferries from the time the sea first changed the character of the river. In modern times, as a consequence of the narrowing of the channel by bridging, embanking, and dredging, the river has been greatly deepened. Above London, for instance, the gravel is excavated to the surface of the London Clay, sometimes in the centre of the stream; but below London the stream runs in a shallow depression in the old river-gravel. There is nothing, in the evidence which we have, to lead us to suppose that the lower plane which I have been describing, if prolonged below Gravesend, will differ

greatly in its inclination for some distance, though of course the upper one may be expected to do so; nor, as the soundings on the charts of the Admiralty permit us to follow the direction of the channel by which the Thames enters the sea, can we have much hesitation in ascribing to the continuation of that channel off the coast of Kent, through the "Warp," the "Oaze," and the "Black Deep" in the North Sea, an indication of the former course of the River Thames when as yet the ocean was far away. The wide-spread Maplin sands, the shallows of the Nore, the Cant, and the Kentish Flats, the Margate sands, and the Girdler, &c., may represent the remains of high land now washed away; nor is there any improbability that a great extension of Sheppey itself, and other islands like Sheppey were once spread over the areas occupied by those waters. As for the former existence of inhabited land, where the Pan Sand and the Pudding Pan "Rock" stands or stood, 2000 years ago, I have no doubt of it. For further details concerning this, and many other like matters, I beg to refer to a paper on the antiquarian side of this question in the 'Journal of the Archæological Institute,' Vol. xlii, p. 269.

Upon the gravels I have been describing lie layers of blue (grey) tidal clay, with beds of peat between, though occasionally the peat is found lying on the gravel. In the highest part of the estuary the blue clay differs but little in its appearance and constitution from the flood-alluvium of the fresh water; but from Richmond eastward, evidence is found of marine influence in the presence of the tests of marine diatoms and the shells of brackish-water gasteropods.

In the upper part of the estuary such peat, or more properly black earth, as we find, is superficial. However, it occasionally dips into hollows to a considerable depth, as was found at Whitehall, where the Serpentine river joined the Thames. At the Surrey abutment of the Tower bridge this black earth is underlain by blue mud (upper layer). A little further down a layer of peat may be found covered with tidal clay (by which name I shall in future call the blue mud) lying at Ordnance Datum. Below this, at about Woolwich, other layers of tidal clay and peat come in, which succession is very marked at Crossness. Between Erith and Gravesend a third layer of peat commences, which is also covered with tidal clay, and which at Tilbury has beneath it slight signs here and there of tidal clay again. This overlies the old river-sand.

The diagram already referred to shows the layers of clay and peat lying horizontally on the inclined bed of gravel; it is much exaggerated vertically. The sections on which this diagram is founded—at Tilbury, Crossness, and numerous places in the marshes—have been so lately open that I excuse myself from giving them here in detail, the more so that Mr. W. Whitaker's 'New London Memoir,' soon about to appear, will, of course, contain many of them.

I take this opportunity of acknowledging Mr. Whitaker's kindness in permitting me to inspect some of his drawings, and otherwise assisting me with reference to the present paper.

The layers of blue clay are distinguished as tidal clay, because I consider that all these deposits shown in the diagram were spread under such conditions as the clay of the Saltings, *i.e.*, clay outside the river-walls, is being spread by the tide now, with the exception that in the older layers drift logs are often found imbedded.

The blue clay contains a large quantity of organic matter in a state of minute subdivision, to the deoxidating power of which its colour is due. In each layer seen at Tilbury, Crossness, or elsewhere shells of *Scrobicularia piperita* appear, generally accompanied by *Tellina balthica*, which distinctly separates it from the little lenticular deposits of mud or sand which lie under, in, or upon the layers of the peat (see Fig. 3), and which usually contain an abundance of land and freshwater shells, seeds and fruits, &c. Where the layers of peat rest on the tidal clay the clay presents a modification of its colour and consistency: it is redder, sometimes bright yellow from peroxidation of its iron; and it dries by breaking up into small dice-like masses, just as the dried surface of the present marsh does. This results from the loss of its organic matter by aëration or weathering, and it is evidence that it had been exposed and become a well-dried land-surface previous to the growth of the forest on it. Little freshwater streams have left their marks in the patches of mud containing land and freshwater shells. In the upper part of each layer of clay beneath the peat abundant roots and rootlets are found, those of trees meandering over the surface at little depth. The trees which constitute the larger part of the peat-beds are easily perceived to have been growing on the spot where found, and constitute with the other vegetation true forest-beds. At Tilbury none of the trees appeared to be of much importance as to size in any of the layers,

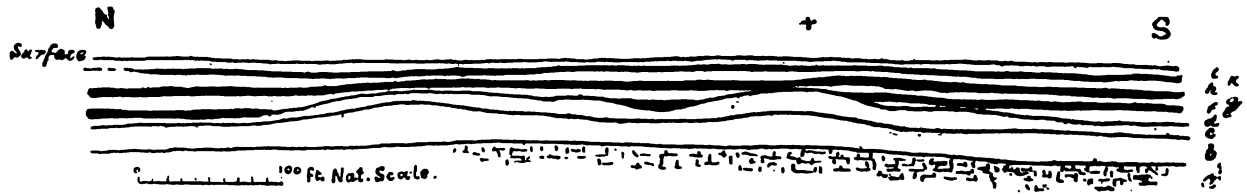


FIG. 2.- Section adapted from one belonging to W. Whitaker, F.R.S., in the Dock excavation, Tilbury.

a, Chalk.
b, gravel } River deposit.
c, sand }
d, tidal clay.
e, peat.
f, tidal clay.
g, peat. } Alluvium.
h, tidal clay.
k, peat (Roman surface).
l, tidal clay.
\+ place where the man lay in sand.

constituting at the best what is called scrub in the mid-marsh section, though larger trees are obtained near the inland shores. In the lowest layer were birch and hazel (rooted), but portions of other trees in horizontal positions were not difficult to find, and some had been drifted. In the middle layer there was scrub in parts and trunks of small size, but the peat mostly consisted of reeds, *Phragmites*, *Sparganium*, &c., with layers of moss (*Hypnum*), and freshwater plants of various species. There was also a marked layer of *Sphagnum* of two species, and with this spores and portions of the fronds of ferns (*Pteris ?*). Among the peat of the middle layer Mr. T. V. Holmes found "Horsetails and Heather" ('Trans. Essex Field Club,' iv, 135). In this layer also I found a wide spread of a very close-grained peat, perfectly homogeneous under low powers, consisting apparently of washings from an old peat-bed relaid. It was from three to six inches thick, and broke with an almost conchoidal fracture, which became more marked when dry; it was translucent at the edges. The upper layer of the peat was comparatively thin, and mainly consisted of a small growth of underwood, with spreads of grass resembling the growth on the marshes at the present day. I think it likely that this layer was much thinned in places in consequence of drought and by the rotting of the surface, due to clearing or agriculture, for on this level the Romans lived. I found the remains of a building in one place, surrounded by the rubbish remaining from a lengthy occupation. Since I wrote the archæological paper to which I have already referred, I have met with several of the navvies who worked there, and have learned that the Roman relics were found over the whole area uncovered by the dock excavation, and that many were in such condition and of such excellence that some of the men were enabled to make a goodly harvest by their sale in London.

At Crossness, where in former years a great area was excavated, another great hole has been dug, and during the last year I have been able to work more carefully than usual there. The section, Fig. 3, gives a view in the centre of the cutting (considerably shortened, however), which applies to the whole area opened up—which is several acres in extent—and presents a state of the marsh soils similar to that visible in the more westerly area. This section, with the previous cuttings for the Metropolitan sewer and

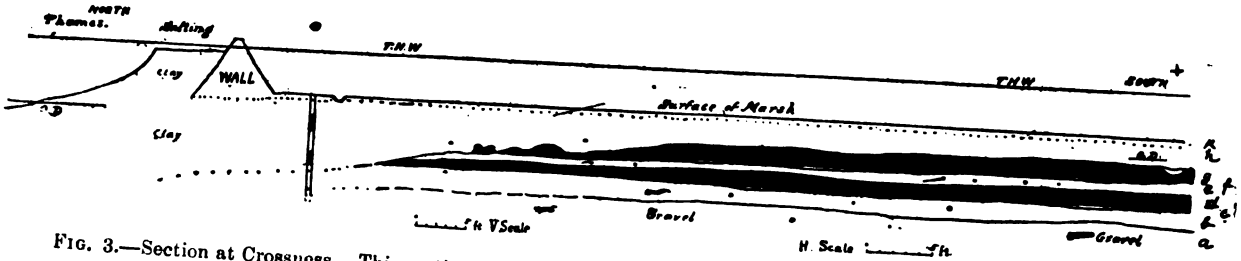


FIG. 3.—Section at Crossness. This section is much shortened, as the southward extension presents no peculiarities.

a, gravel, becoming sandy on the North.
b, sand.
c, lenticular thin beds of sandy clay full of fresh-water shells.
d, peat, lower.
e, tidal blue clay.
f, beds of sand and shells as above.
g, peat, upper.
h, tidal clay.
k, arable soil and so-called brick-earth.

} Alluvium.

The black marks represent drift-wood.

o, a boring 150 yards west of this point, showing the same layers of peat, etc.

from which the outer parts had been riven, apparently to make shingling. Bricks and roofing-tiles were found. In great contrast to what I have observed (in the paper already mentioned) with respect to the Roman relics lower down in the Swale marshes, it is likely that the Roman occupation of this district was more leisurely terminated, and no ruins of value left behind. When the tide water regained superiority and washed the surface of the forest soil it destroyed some depth of that surface altogether. It also washed about some of the sherds, leaving them with rounded edges, resembling those now found in like condition on the shores and saltings lower down at East Tilbury or Upchurch. These sherds lay mixed with the lowest part of the clay on the peat. The tide also washed away parts of the peat-beds here, in bay-like hollows, so that portions slid away from the mass and were seen, as the cutting proceeded, standing isolated in the blue clay, just as is now happening in other places, while above and below this spot the two layers can be found intact close to the water's edge. The tide-way of the river in various places on both sides below Woolwich, especially about Erith and Purfleet, at low water, shows broad strips of forest-bed, the upright stubs of trees being surrounded by a dense and complicated network of roots. Fallen trunks of trees also lie awash. From these old surfaces are obtained now and then vases of Roman ware, some of which, as at Erith and elsewhere, have formed part of burial deposits.

A slight alteration in the current of the river having permitted a redeposition of mud off the Crossness shore, the layer which covers the Roman remains, and which now serves for agricultural purposes, was extended into the stream. The figure (Fig. 3), very well illustrates the growth of the modern fresh marsh; the level from which the present wall was raised; and the accumulation outside it called "salting," which has continued in certain situations ever since the Romans abandoned the spot.

The different cuttings, as they are followed westward, exhibit the two layers of peat separated by clay, which is more and more filled with drift wood until the junction of the Thames with the Lea and the Ravensbourne is reached. At this part of its course the amount of drift wood is so great as to obliterate almost completely the distinctions I have laid down between the clays and peats. At the Albert Dock excavation big trees interlaced at

various angles in such a way as practically to make the peat-beds one, and not a forest-bed, except at its upper level, where the advent of quieter times enabled the forest to re-establish itself and to present a more regular surface. Here also were found Roman remains, but, as might be expected, less in quantity, from the inconveniences of the floods originating with the River Lea.

In certain places in the alluvium, and notably near Gravesend, the peat presents wavy outlines in section. These, there can be no doubt, are the result of changes which have for the most part occurred subsequently to the deposition of the layers of clay and peat. The streamways from the land would be freshwater streams when the forest or land surface was above reach of the tide, and they would be *fleets* when the tide overflowed the low lands. When the clay was deposited the level would be, like it is now, at a uniform height, but there would be still a slight disposition for the beds of clay, especially during dry periods, to flow into the lower gullies. This, though very slight, becomes perceptible in the lapse of ages. When the clay slips or flows, the peat does not stretch, it therefore breaks and the clay flows into the break or crack, usually from the layer above which is more plastic than the lower one. (See Figs. 4 and 5.) An apparent case of incipient or extra peat-surface was well shown at Tilbury at a considerable distance from the river in consequence of a slip of the clay having carried a thin layer of the peat (middle) away with it, leaving it dissociated from the parent mass and apparently an independent layer.

There are clear instances also in which the flow of underground streams has abstracted by dissolution, calcium carbonate and organic materials from the gravel, and others in which the peat has been dissolved along certain lines by oxygenated water flowing down them; these causes would likewise produce the gentle waviness seen in a section. There are cases, too, in which the water has found it way through the gravel within the bank where a fleet has at one time weakened the layer of clay sufficiently to enable the water to rise through it; and then, when the tide has fallen and so withdrawn its support to a bank, the weight behind, aided by land floods, has burst the bank outwards. Such a reason, I suppose, may account for the continual recurrence of breaches in particular

places—those of Dagenham and the great and lesser breaches of the Erith marshes being cases in point.

Hitherto it has been the rule to speak of the forest-beds as *the* forest and *the* peat, with indefinite divisions of peat in it at the most.

On the other hand, a section compiled from borings and hasty notes is liable to present an appearance of irregularity in the deposits, for frequently it may happen that a stray drift log in the clay may be recorded by the engineer as a layer of peat and so the layers be unduly multiplied, not to say mixed, by the effort of imagination required to connect them.

But I find the relative positions of the various layers in the alluvium to each other very constant, and the variations from the order in which I have described them as occurring, to be all explicable by ordinary events and accidents of a kind which in no way confuses.

Near the edge of the river at Tilbury there was disclosed on a sudden an increase in the layers of peat, all horizontal in position. These I found had been caused by pressure from the side towards the river. Portions of peat had been dislocated from the main mass, which, rising vertically in the manner of steps, presented the appearance so well illustrated by Mr. Marr's models of Stresses. In another case, at the river's edge at Tilbury, the main peat layer was to be seen thrown into a fold with vertical sides in such a way as to show a great thickening, which measures taken through it for purposes of a section would misrepresent. The upper part of the fold had subsequently suffered denudation horizontally, and clay and peat could be seen lying normally over it (Fig. 7). Another fold was seen less distorted near the same place (Fig. 8). Doubtless all these cases were connected. I can only account for the appearances by the supposition that once on a time ice blocking up the river had exerted so much lateral pressure that the soft ground began to crumple and give way. Even in historic times the Thames has been blocked by ice at Gravesend, as has been recorded to have happened in 1281, if not later.

As all the layers of peat before-mentioned were distinctly dry land surfaces, while the layers of clay represent salt-marshes subject to the tide, the alternate layers of alluvial peat and clay

represent interrupted subsidence of the land beneath the sea-level. That this was very gentle during the deposition of the clay is obvious from the fact that, at various levels in it, there are sometimes found signs of roots and a thin peat formed of brackish-water plants with *Phragmites*, such as now grow in similar situations; but it is not certain whether there was a mere arrest of subsidence or a positive rise in the land which allowed the forest to occupy the bottom lands and fringe the comparatively narrow stream. From the moment when the gravel was laid on the bed-rocks of the river until now there has been no break in the continuity of the deposits, the only difference being that of kind with a gentler display of force—thus, river-gravel, sand, clay, and peat. The last layer of clay is being deposited at this moment over old gravels in spots which have never been covered by it before. Even the latest layer contains concretionary masses, somewhat pappy on the outside, consisting of calcium carbonate mixed with arenaceous and argillaceous particles with a little iron and phosphoric acid, which I take to be an incomplete form of such masses as are known by the name of *Race*. For the rough analysis of these masses I am indebted to Mr. W. H. Hudleston, F.R.S. I procured some of these in the Sheppey marshes seven feet below the salting top and about four feet above the layer of Roman remains and burnt clay flooring.

The tidal clay, which in suitable places is still being accumulated, is kept up to the regular height far down the estuary, although the washing away of the land by the sea is destroying the area of the saltings, and even of the enclosed marsh, the efforts to preserve which often exceed the profits derived from its use. I have mentioned that the embankment and confinement of the river to a narrower channel has deepened the streamway, and it is obvious that, were the embankments not kept up, even at a loss, the spreading of the tide would rapidly produce shoals and a general shallowing of the water. If we carry our minds further back to times when the tide was absent, the marshes covered with loosely-rooted trees and only the comparatively small freshwater (or perhaps sometimes brackish) stream filling the channel, we can well picture to ourselves the great banks and shoals which made a passage of the river by fords and boats an easy matter. When further we consider that the accumulation of stranded trees combined to

aid this it will not be difficult for us to picture nature assisted by art, and even bridges and causeways jutting out into such a stream as the present estuary of the Thames was when the Romans first came here. It is, I think, not too much to suggest that the tidal water, such as now reaches London, might then have been full five-and-twenty miles away.

The only skeleton of man which has been investigated from the estuary of the Thames is that of the "Tilbury man." It was found in the bank of sand shown in Fig. 2, under the mark +, covered by twenty inches of sand. This sand I followed vertically to the gravel, of which it constituted a part. A few shells of *Bythinia* and *Succinia* were also obtained from it. On the surface of the sand lay a few stray valves of *Scrobicularia* and of *Tellina*. The skeleton was not that of a well and equally formed man.

Sir R. Owen has described the skeleton and its situation (Sir R. Owen, 'Antiquity of Man') and has pronounced that it is a Palæolithic man. Mr. T. V. Holmes ('Trans. Essex Field Club,' iv, 135) has examined the situation in which it was found and he pronounces the man to be Neolithic. Prof. Prestwich ('Geology,' ii, 522) says that he was "a very ancient, but not Palæolithic man" which taken with the opinion he gives that there is a distinct break between the two "*lithic*" ages, clearly marks him as Neolithic.

No implements were found with the skeleton, nor in the excavation in which it was found. I may be pardoned, therefore, if I examine the value of these opinions.

As yet no Palæolithic implements have been actually found in the gravel series to which this man belongs, and which, on Fig. 1 is marked (*a*). Neither have any been dredged up from the river, nor have any Neolithic remains been found in place in the gravel. All this is not very surprising seeing the difficulty of examining or even of getting a good view of these deposits. It is altogether from the operation of dredgers that we have at present any stone implements from the deep gravels of the Thames, and these are exclusively, so far as I know, Neolithic. Very many rude as well as polished implements have been obtained by this means, but no series of implements forming a peculiar type has been got from this situation.* By Palæolithic deposits is understood

* After this paper had been sent in I received a letter from Mr. G. F. Lawrence, of Wandsworth, telling me of some flint implements he had lately obtained from the Thames. These implements were brought to Wandsworth

FIG. 4.

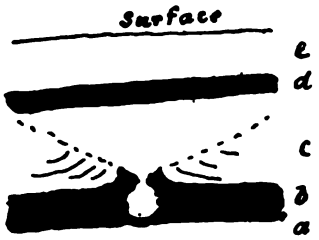


FIG. 5.



FIG. 6.



FIG. 7.

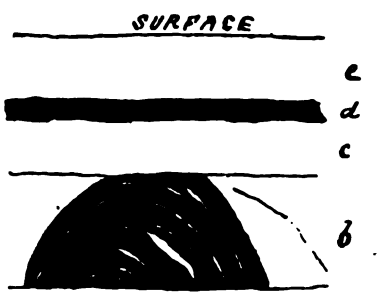
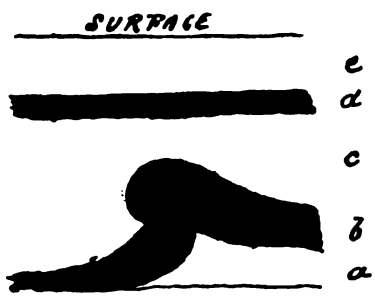


FIG. 8.



FIGS. 4-8. Figures representing the peculiarities in peat at Tilbury. The lettering in each signifies the same layers, *b* in each case being the middle or main peat. They are sketches approximately to scale.

those in which implements having that title are found, and in which they have a contemporaneous place. A similar statement will define Neolithic deposits, but the presence or absence of extinct Mammalia does not affect these definitions. There is no doubt that Palæolithic implements, taken as a whole, may be separated from Neolithic implements similarly considered; but it would be a mistake to deny that there is a distinction to be made in the types of each class which points to variation in a certain direction. To say that there is no passage between the two leading classes of implements is to say too much; and it is assuming still more if this necessitates the supposition that man was absent altogether during the very time when that amelioration of the climate was in progress which resulted in the gradual improvement which has continued from Palæolithic times until now.

It is obvious then that between the two kinds of implements there must be an approximation somewhere, and if the question is unsettled it is merely for want of investigation. From what has already been advanced I see no reason why the evidence of this approximation or transition should not be discovered in the deposits of the estuary I have been examining.

On the whole, it appears to me that the man of Tilbury holds a middle or transitional position.

In the case of the extinct Mammalia with which he is to be considered, we find that a few species, including the Elephant, continued to live through the period of deposition of the gravel and sand to its junction with the Alluvium, and some are found high up in the latter. I think, too, the Tilbury man may have been a contemporary of the Mammoth.

The teeth of the Mammoth have been found by dredgers not

with gravel which had been dredged off Erith, or somewhat to the eastward of that place, in the autumn of 1888. On visiting the writer I found that two implements in particular which had been found at some little distance of time and place from each other were well worthy of notice. If in some points they resemble Palæolithic types, in others they are like Neoliths. Their workmanship is good, they have received no recent injury, and their mineral condition, marking, and colour are in perfect keeping with the appearance of the gravel of the place whence they came. Their most remarkable feature is that they resemble no implements from the neighbouring Palæolithic deposits, nor any others yet discovered in this part of the country; they appear to confirm my views expressed in this paper that there is a transitional type.

unfrequently when working in the Thames, but it is to be regretted that comparatively few specimens have been preserved. I have a good one, obtained off Price's Oil Works at Erith, which I propose to present to the British Museum. The dredge was at work very close in shore when the tooth was brought up, and it could only work at high-water, resting on the dry mud and forest-bed long before the ebb. The tooth evidently lay partly in sand and partly in peat, and when it was brought to me it was covered with the latter. It is markedly of the Arctic type. I also have a portion of a large tusk from (off) Dartford. This evidently lay in contact with peat on a layer of gravel, which adheres to one side of it. It is very black on the outside, and within are blue patches of iron phosphate. In Jermyn Street Museum is a molar marked "Dartford." It is in excellent condition. The matrix is at one part sand, and at another blue clay. It is very deeply stained with peat, and evidently dredged from the Thames off the parish named. Another in the same Museum, marked "Erith," has a great similarity to the Dartford specimen as to colour and adherent matrix. Two teeth were obtained from a navvy by Mr. Davies, and placed in the British Museum, Catalogue No. 40,081. They came from excavations apparently connected with the West India Docks in the Isle of Dogs. The matrix is sandy, and they are deeply peat-stained. Another in the British Museum, No. 37,248, was obtained from Millbank; is black and unworn, and was apparently dredged or obtained from a cutting in the peat. Last autumn Mr. E. R. Pearce wrote to tell me that he had a molar of elephant which had been dredged off Greenwich. I found it to be in a similar condition to those above mentioned. All these teeth are remarkably well preserved and very dark. They seem to belong to the Arctic type of Mammoth. They are very heavy, and seem to still retain some portion of gelatine. The matrix in every case shows that they laid near the peat or in it. Dr. H. Woodward has recorded the finding of elephant molars in and upon the gravel below the peat at Walthamstow, and there is one tooth in the British Museum, No. 40,559, in a sandy matrix and black, from the Medway.

It has been suggested to me that these teeth have been "derived." Had I thought so I should not have gone into details. The specimens are not rolled, and the laminæ of cement

in some instances are very thin. Their physiological condition also is so similar to other remains from the same horizon, such as the *Homo* of Tilbury, *Cervus tarandus*, and other animals, that I see no cause, apart from theory, why one or another should be separated by calling it derived.

The remaining animal-remains are a few of those which I have been able to collect or to hear of.

Arvicola, sp.
Bos longifrons.
Bos primigenius, "Urus," Albert Dock.
Canis lupus, common.
„ *vulpes*, ditto.
„ sp. "Dog," ditto.
Capreolus capra, Albert Dock.
Castor fiber, Albert Dock and Crossness.
Cervus alces, in peat near the junction of the Lea River.
„ *elaphus*, most abundant.
„ *tarandus*, not infrequent, and extending to the upper level of the peat.
Equus caballus, Crossness.
Sus scrofa.

The following list of plants is constructed from their leaves, wood, and seeds I procured the seeds by an exhaustive method of washing, and think it probable that it represents the larger proportion of those recoverable. I am indebted to Mr. Clement Reid, F.G.S., for kindly looking over and identifying those here given; but I still possess some which are undetermined. I collected from the separate beds at Crossness between 30 and 40 specimens of wood, from trees whose diameters ranged between 10 inches and 2 feet. Prof. H. Marshall Ward, F.R.S., kindly undertook to examine my mounted sections of these, and though the kinds were few, *Pyrus* and *Salix* were added to the list, the majority proving to be *Fraxinus* and *Alnus*.

List of Plants.

L = lower. U = upper beds at Crossness. A = lower part of alluvium of Albert Dock, North Woolwich. T = base of main layer of peat at Tilbury.

	L	U	A	T
Ranunculus sceleratus, L.	×	...	...	...
Ranunculus repens, L.	×	×	...	...
Oxalis Acetosella, L.	...	×	..	...
Prunus communis, Huds., several different forms, perhaps including ***Bullace***	×	×	...	...
Prunus spinosa, L.	×	...	...	...
P Cerasus, L.	×	×	...	...
Rubus fruticosus, L.	×	×	...	...
Rosa, sp.	×	×	...	...
Pyrus communis, L.	×	×	...	...
Cratægus Oxyacantha, L.	×	×	...	...
Ilex Aquifolium, L.	×	×	...	...
Viburnum Opulus, L.	×	×	..	...
Hippuris vulgaris, L.	...	×	...	...
Œnanthe Phellandrium, Lam.	...	×	...	...
Hedera Helix, L.	×	×	...	..
Cornus sanguinea, L.	×	×	×	...
Sambucus nigra, L.	×	×	...	×
Fraxinus excelsior, L.	×	×	...	...
Polygonum Hydropiper, L.	×	...	...	...
Mercurialis perennis, L.	×	×	...	...
Salix, sp.	..	×	...	...
Betula alba, L.	×	×	×	×
Alnus glutinosa, Gaertn.	×	×	×	×
Corylus Avellana, L.	×	×	×	×
Quercus Robur, L. ***sessiliflora***	...	...	×	×
„ „ ***pedunculata***	×	×	...	...
Acer campestre, L.	×	×	...	...
Taxus baccata, L.	×	×	×	...
Iris Pseudacorus, L.	...	×	...	...
Sparganium ramosum, Huds.	×	×	...	×
Scirpus lacustris, L.	×	...	...	...
Carex, sp.	...	...	...	×
Phragmites communis, Trin.	×	×	×	×
Pteris aquilina, L.	...	...	...	×
Sphagnum, two species	...	...	...	×
Hypnum, spp.	×	×	...	×
Hypoxylon concentricum	...	×	...	...
Polyporus hispidus, Fr.	...	...	×	...
Puff-ball, species undetermined	...	×	...	...

List of Shells.

L = lower peat. U = upper peat, Crossness. A = Albert Dock. T = Tilbury main peat.

	L	U	A	T
Pisidium amnicum, Müll.	...	×	×	...
„ *fontinale*, Drap.	×	×	×	...
Sphærium corneum, L.	×	×	×	×
Unio tumidus, L.	×	×	×	...
Neritina fluviatilis, L.	×	×	×	...
Valvata piscinalis, Müll.	×	×	...	...
„ *cristata*, Müll.	×	...	...	...
Bythinia tentaculata, L.	×	×	×	...
„ *leachii*, Shep.	×	×	...	...
Hydrobia ventrosa, Mont.	×	...	...	×
Planorbis fontanus, Lightf.	×	...	...	...
„ *contortus*, L.	×	×	...	...
„ *spirorbis*, L.	×	...	...	...
„ *marginatus*, L.	×	×	...	×
„ *crista*, L.	...	×	...	...
Limnæa truncatula, Müll.	×	...	...	×
„ *palustris*, Müll.	×	×	...	...
„ *peregra*, Müll.	×	×	×	×
Ancylus fluviatilis, Müll.	×	×	...	...
„ *lacustris*, L.	×	...	...	...
Carychium minimum, Müll.	×	×	...	×
Succinea elegans, Risso.	×	×	×	...
Clausilia laminata, Mont.	×	×	...	...
„ *rugosa*, Drap.	×	...	...	...
Balæa fragilis, Drap.	×	...	...	...
Vertigo pusilla, Müll.	×	×	...	×
„ *substriata*, Jeff.	×	...	...	...
„ *edentula*, Müll.	×	...	...	...
Pupa umbilicata, Drap.	×	...	...	...
Cochlicopa lubrica, Müll.	×	×	...	...
Helix nemoralis, L.	×	×	×	...
„ *arbustorum*, L.	×	...	...	...
„ *lapicida*, L.	×	...	...	...
„ *rufescens*, Penn.	...	×	..	...
„ *concinna*, Jeff.	×	...	...	...
„ *hispida*, L.	...	×	...	...
„ *pulchella*, Müll.	×	...	...	×
„ *rotundata*, Müll.	×	×	...	...
Ova of *Helices*	...	×	...	...
Hyalinia nitida, Müll.	×	×	...	...
„ *fulva*	×	...	...	...
„ *nitidula*, Drap.	×	×	×	...
„ *crystallina*, Müll.	×	...	...	×
„ *cellaria*, Müll.	×	...	...	...

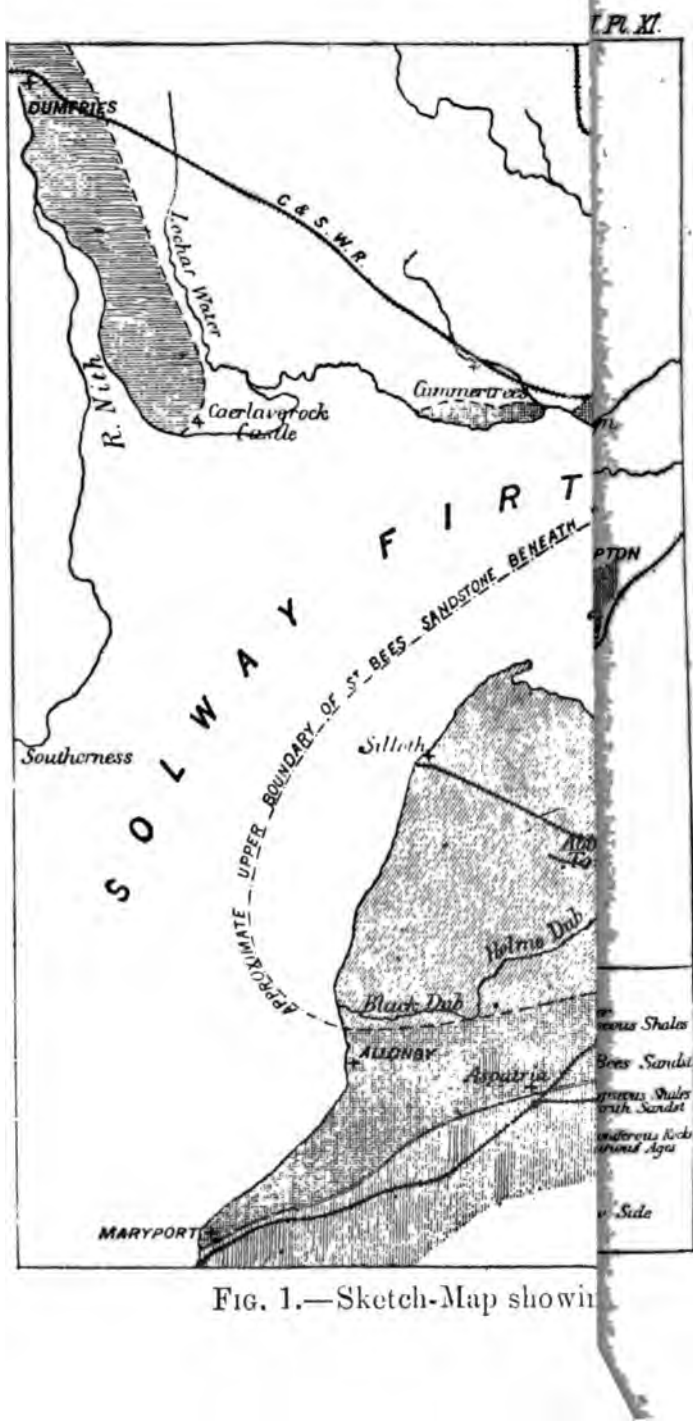


FIG. 1.—Sketch-Map showin

The Geology of North-West Cumberland.

By T. V. Holmes, F.G.S., President.

(Read July 5th, 1889.)

I.—The Carboniferous, Permian-Triassic, and Liassic Rocks.

It is obvious, on glancing at a geological map, that the Carboniferous rocks of this district encircle the Silurian strata of the Lake Country, and are themselves encircled by the Permian-Triassic beds. They consist of beds of limestone, sandstone, shale, and coal, thick limestones being found only among the lowermost beds of the series, in the high ground just outside the mountain country. There the fells rise to a height of 1,000 to 1,200 feet or more, while as we approach the Solway the average height of the ground gradually diminishes. On the day of our ascent of Chalk Beck we shall begin our walk on the St. Bees Sandstone at a height of about 200 feet above the sea, and arrive before the end of the day among the Carboniferous Limestones and other beds of Warnell Fell at a height of between 900 and 1,000 feet.

Chalk (Shalk, Shawk, or Choke) Beck affords an admirable and almost continuous series of sections in the Carboniferous strata intermediate between the lowest beds, in which thick limestones predominate, and the Coal-measures or uppermost division. It will be found that, though there is limestone of Carboniferous age near the old lime-kiln, just above the spot at which the Carboniferous-Permian-Triassic junction is seen, no more bands of limestone are visible nearer than a spot just below the house called Ninegills, about three miles higher up the stream, the measures seen consisting of sandstones and shales. These beds vary in the direction of their dip from about 10° north of east to 10° east of north, the amount being often high. Their colour varies, but is frequently reddish or purple-grey. At Ninegills a fault ranges across the Beck in a north-west and south-east direction, having a downthrow to the south-west, so that while from the Permian-Triassic boundary

to Ninegills we have been gradually traversing lower and lower beds, we are, after crossing this fault, on beds geologically higher than those a few yards down the stream. These higher beds above Ninegills are considerably redder in tint than those just below the house, though not more so than the measures a mile or more nearer the Permian-Triassic junction. On getting on to the high common, a little beyond the head of Chalk Beck, indications of many old coal-workings may be seen. Hutchinson (Vol. ii, p. 390) quotes some remarks by a resident at Caldbeck on the Warnell Fell coal, from which it appears that this coal was worked in a pit there, where it was found at a depth of 55½ fathoms and was 16 inches thick. The following is the section given, reduced to feet:—

	Thickness.	Depth.
Clay	60ft.	60ft.
Day freestone metal	24ft.	84ft.
Day freestone	84ft.	168ft.
Day freestone metal	84ft.	252ft.
Day limestone	9ft.	261ft.
Main limestone metal	33ft.	294ft.
Main limestone...	12ft.	306ft.
Coal freestone	18ft.	324ft.
Grey-beds and metal	9ft.	333ft.
Coal	1ft. 4in.	

The term "metal" means shale. In three boreholes on the Warnell Estate made in 1888, one 29 feet 6 inches deep, another 85 feet, and a third 105 feet, neither coal nor limestone seems to have been met with. At Denton Holme Colliery, Sebergham (Engine Pit) the section was:—

	Ft.	In.	
Soil, clay, and gravel ...	23	6	
Sandstone and shale... ...	88	0	
Hard, grey limestone... ...	13	4	
Sandstone and shale	17	6	—142·4
Coal	1	8	

These sections are given both to illustrate the average thicknesses of the coals which have been worked on this geological

horizon hereabouts and the nature of the beds associated with them. But one thin limestone band occurs in each of the two collieries.



Fig. 2.—Diagrammatic Section from Shalk Beck, above East Curthwaite (N.), across Warnell Fell (S.). Distance, about six miles.

The lowest Carboniferous beds in the neighbourhood of Caldbeck, those in which thick limestones predominate, are so much dislocated by faults and obscured by drift that any given bed of limestone is with difficulty traced for more than a mile, if so far. For example, if on arriving at the common a little beyond the head of Chalk Beck we proceed in a south-easterly direction, in order to inspect the thick limestones about Park head before descending to the village of Caldbeck, we find below the Parkhead Limestone two other massive beds of that rock, which make bold escarpments on the fine hillside between Parkhead and the stream called the Caldbeck. But to get to the village of Caldbeck we must go from Parkhead, not in a southerly, but a south-westerly direction, for a distance of about a mile.

However, instead of crossing, as might be expected, the thick limestones below that of Parkhead, we find no signs whatever of their existence, such beds as are visible being sandstone and shale, while here and there old coal-work-

ings, such as we saw on the top of Warnell Fell, appear. In short, a fault, ranging about N.N.W. and S.S.E., with a downthrow to the west, crosses the hillside, and throwing down the limestones some distance, gives us at the surface in their stead, measures such as those which overlie the limestones on the top of Warnell Fell. The sudden disappearance of the limestone terraces on the hillside is well shown from the road between Caldbeck and Hesket Newmarket, which commands a fine view of the bold hillside north of the stream.

The most common fossils in the limestones are encrinites; but in some a species of *Productus* is very abundant.

The experience gained in Chalk Beck, to the effect that limestone beds are few and thin as we ascend in the series, is one that would be confirmed should any other route be taken from the low ground near the Solway to the Limestone Fells.

I have already stated that though we started from the Permian-Triassic junction at Chalk Beck, the uppermost Carboniferous rocks there visible are on a lower geological horizon than the measures of the Coalfield of the coast between Whitehaven and Maryport, which forms a narrow belt of country south of the Permian-Triassic area about Dearham, Blennerhasset, and Mealsgate. The north-easterly prolongation of this coalfield, from Dearham to Mealsgate and Bolton-Low-Houses, is due to the existence of a line of fault, ranging in a north-easterly and south-westerly direction, a little northward of Plumbland, Torpenhow, and Boltongate, which has a downthrow to the north-west. The effect of this fault may be thus pointed out. We have seen that in Chalk Beck there is a vast thickness of beds of sandstone and shale, with scarcely any limestone, between the thick limestones of the fells and the Permian-Triassic boundary. Now if we travel five or six miles westward of the upper part of Chalk Beck we come to Catlands Hill, where thick limestones predominate. But instead of a series of rocks such as we found in Chalk Beck, directly northward of Catlands Hill we have collieries in which are, or were, worked the thick coal-seams of the Coal-measures proper, the intermediate series existing in the Caldew and in Chalk Beck ceasing to appear at the surface at all. Considering the shortness of the distance between Chalk Beck and Catlands, and the great thickness of this intermediate series, it is obvious that

the existence of a line of fault of great magnitude is the only agency which will account for the state of things observed. (See Fig. 3.)

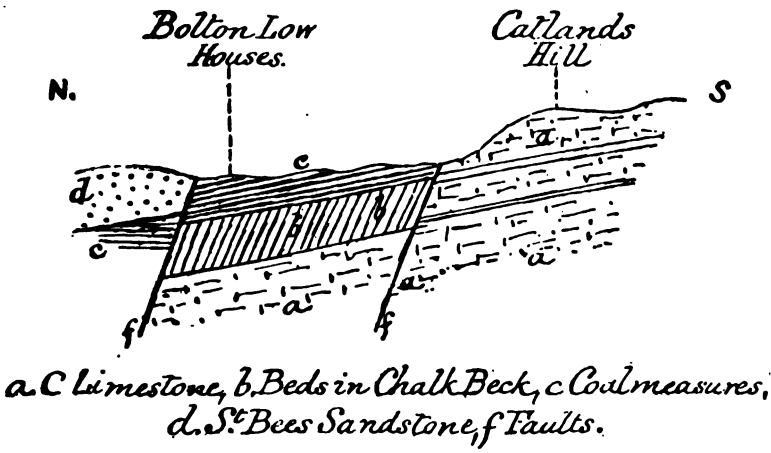


FIG. 3.—Diagrammatic Section from Catlands Hill to Bolton-Low-Houses.

I need say nothing about the Coal-measures of the Whitehaven and Maryport Coalfield as regards the thicknesses of the coals worked there, or the average distances between those of most repute; but there is a certain bed which we shall see between Whitehaven and St. Bees which merits some little attention, viz., the rock known as the Whitehaven Sandstone. This is of a generally purple-grey colour, and is seen to rest unconformably on Coal-measures with sandstones of a brown or buff tint. This unconformity, together with the colour of the Whitehaven Sandstone, caused it to be supposed at one time that its affinities were rather Permian-Triassic than Carboniferous, and it is accordingly classed with the former by some of the earlier writers on the geology of this part of Cumberland. Its position, however, in the Cumberland Coalfield is precisely analogous to that of the Red Rock of Rotherham in the Yorkshire Coalfield. It is an Upper Carboniferous rock, being at the same time unconformable to the Carboniferous rocks, on which it rests, and to the Permian-Triassic series above. It is known to exist in many places east and north-east of Whitehaven, and we shall obtain a glimpse of

it at Rosegill, between Bullgill and Dearham Railway-Stations, where there are quarries in it.

But though at Whitehaven it is distinguished among the Carboniferous rocks by its redder tint, the Whitehaven Sandstone is by no means remarkable among the Carboniferous strata of Cumberland generally on account of its colour. Beds of pinkish or purple-grey tints are more or less common at every stage of the Carboniferous Period, and in every part of Cumberland where Carboniferous rocks are seen. They abound in Chalk Beck, the Caldew, in the Waver near Bolton-Low-Houses (on the Coal-measures proper), and northward in the Esk, the Line, the Hetherburn, and other streams. One consequence of the erroneous notion that beds of these colours were necessarily on the Whitehaven Sandstone horizon, and were of Permian-Triassic affinities, is shown in all old geological maps of this district. There we find the Permian-Triassic boundary ranging due east from Aspatria towards Caldbeck, so as to include as New Red Sandstone the whole of the Carboniferous Rocks of Chalk Beck, the line being drawn a little northward of Caldbeck, so as to exclude the old coal-workings of Warnell Fell. Thus, by this rash reliance on colour, unsupported by other evidence, beds which, as we have just seen, are of Coal-measure age, were classed with others of earlier date as alike Permian-Triassic.

Alike at St. Bees Head, however, in Chalk Beck, and at every other place where the Carboniferous junction with the overlying rocks is visible, we shall find that the characteristic tint of the Permian-Triassic stone is brick-red, and that of the Carboniferous rocks, where they are brightly coloured, pinkish or purple-grey. In many cases fragments of Carboniferous Sandstone may be seen lying about here and there which have precisely the appearance of fragments of St. Bees Sandstone; but on breaking the fragments with a hammer the purple-grey colour becomes at once manifest. So invariably has this change of hue been noticed to accompany an unconformable junction, that the geologist can now feel a confidence in this colour-test, where other evidence is unavailable, that would otherwise be wholly unjustifiable.

In the Kirklinton district we shall also have opportunities of seeing something of the Carboniferous rocks of pre-Coal-measure

age; but as the sections seen there have no special interest as Carboniferous sections, it seems best to defer any notice of them till those localities are described in connection with the Permian-Triassic rocks.

II.—The Permian-Triassic and Liassic Rocks.

In this district, west of the Caldew, we see nothing of the great Penrith Sandstone, the lowest of these beds; for only about Rose Castle does it probably cross the Caldew, and there it probably covers but a few acres west of the alluvium of that stream. North and east of Carlisle it nowhere is visible, as two faults, which abut against each other close to the Petterill, a few yards above Newbiggin Bridge, and have, both of them, a downthrow to the north or north-west, throw down the great (upper) Sandstone of St. Bees against the great (lower) Penrith Sandstone. North of these faults, the more westerly of which ranges from Newbiggin Bridge to the Caldew, a little northward of Rose Castle, while the other's course is from Newbiggin Bridge to Brackenbank on the Eden, the Penrith Sandstone is nowhere seen in Cumberland. We shall see, during the Kirklinton Excursion, in Carwinley Burn and the Hetherburn, that, putting aside a very thin breccia, the St. Bees Sandstone directly overlies the Carboniferous rocks in that quarter. Nothing is seen of the Penrith Sandstone in the Esk or Liddel, the Kirtle Water or the Annan Water, on the Scottish side of the Border; but a massive rock much resembling it, and containing thick beds of breccia, may be seen east of the Nith, between the town of Dumfries and the castle of Caerlaverock.

Of beds below the St. Bees Sandstone, therefore, we shall see but little, and that little almost wholly during our Excursion to St. Bees Head. The section at Barrowmouth, according to Sir R. Murchison and Prof. Harkness, consists of —

	Ft.
St. Bees Sandstone	1,000?
Red Marls, with gypsum interstratified ...	30
Magnesian Limestone, thickening inland ...	11
Breccia	3

The breccia rests upon Carboniferous rock. Thus the great mass of Penrith Sandstone, which where the Magnesian Lime-

stone is seen in the Eden Valley district underlies it, does not here exist.

Between St. Bees Head and Maryport marine denudation has swept away the St. Bees Sandstone. But it reappears in quarries close to Maryport, and in others between Aspatria and West Newton. We shall pass a quarry close to the railway west of Brayton Station, and shall be able to inspect a series of good sections of the Sandstone in Chalk Beck, between East Curthwaite and the road from Near Welton to Rosley Rigg. We shall also see it in the Kirklinton district and the Eden Valley.

The difference in appearance between the St. Bees and Penrith Sandstones is very marked. The Penrith is of a lighter and brighter red, and is false-bedded on a very large scale. The St. Bees Sandstone is finer in grain and of a deeper red, and is seldom false-bedded. Occasionally bands of lighter coloured stone, buff or whitish, are found in it. Towards its base it becomes very thin-bedded and flaky, resembling what would in some parts of the country be called stone-bind, or sandy shale. This will be seen in Chalk Beck, and near the junction with Carboniferous rocks at Hethersgill. The unconformity at Hethersgill may be seen in the stream where it bounds the field south-east of the Grainhead farm-buildings. It is a little above the bridge.

On the Line near Brackenhill Tower a fault, ranging nearly north and south, brings in the Carboniferous rocks on its eastern side, against the St. Bees Sandstone. Above this point Carboniferous Beds only are seen. The scenery of the Line between Cliff Bridge and Shank Bridge is extremely picturesque, as well as highly interesting geologically. I trust we may be able to walk along the bank of the river from the Brackenhill Fault as far as Cliff Bridge. In Carwinley Burn the St. Bees Sandstone is seen to be extremely thin. On the other side of the Border it must attain a much greater thickness between the Sark and the Annan Water.

Thus, northward of the two faults, between Brackenbank on the Eden and Rose Castle on the Caldew, the St. Bees Sandstone is the oldest of the Permian-Triassic rocks of Cumberland. It is also evident from its southerly dip about Annan, and its northerly dip about Chalk Beck and Aspatria, that it forms the outer formation of a geological basin—which I have elsewhere

called the Carlisle Basin—the western margin of which is below the Solway. We have now to notice the various formations in the Carlisle Basin which overlie the St. Bees Sandstone.

Above it, east of the Lias outlier, is a very soft, usually bright red, false-bedded sandstone, which I have called the Kirklinton Sandstone; but west of the Lias, borings have revealed the fact that resting directly above the St. Bees Sandstone are about 700 feet of gypseous shales. There is no evidence sufficient to settle conclusively which is the older formation, but it seems to me that what is available gives a slight presumption in favour of the greater age of the Gypseous Shales. I will, therefore, deal with them first.

A boring made about fifteen years ago, near Abbey Town, disclosed the fact that below nearly 200 feet of beds belonging to the Glacial Drift there were about 700 feet of Gypseous Shales resting upon St. Bees Sandstone. And another boring, made some time before that, near the west end of Bowness, at high water mark, had shown the presence there of 367 feet of Gypseous Shales below 41 feet of Glacial Drift and above St. Bees Sandstone. Eastward of these two places the only evidence of the existence of these Gypseous Shales is in the record of an old boring near Great Orton. There, below 18 feet of Drift, and 210 feet of rock evidently Liassic, was "red stone or clay, sometimes mixed with veins of white," to a depth of 360 feet, or 142 feet of these beds at least, the boring having been ended in them. As the gypsum at Abbey Town was in thin laminæ, this description of the undermost rock of the Orton boring suits the Gypseous Shales very well. But the only evidence of the existence of this formation is that of the three borings I have named. Nothing that can anywhere be seen eastward of Orton would suggest the remark "These beds are evidently the Gypseous Shales."

I now come to the Kirklinton Sandstone. From my remarks on the Gypseous Shales it is evident that we have no evidence whatever that they lie unconformably on the St. Bees Sandstone. As it seems to me that there is evidence that the Kirklinton Sandstone does do so, I have treated the latter as the newer formation. In appearance this sandstone is very unlike that of St. Bees. Except in its upper beds, as shown in Skew

Bank, north of Grinsdale, and reported in certain borings at or near Carlisle, its colour is of a bright, almost scarlet red, sometimes mixed, more or less, with white. But the Skew Bank Sandstone is almost quite white, and the borings alluded to mention much stone of that colour. It may be seen near Carlisle, at Holmhead, and Cummersdale on the Caldew, at Rickerby, and near Holmgate, on the Eden, and in the Hetherburn, between Hether Bank Bridge and Cliff Bridge. In the Line there is an excellent section at Cliff Bridge, and thence as far as Shield Green, the last-named place being between Kirklinton Hall and the Muckle Linn. Below Cliff Bridge it is seen in the Line at Westlinton and at Metal Bridge, just below the junction of the Line and Esk, while in a boring at Linehow, or Justice Town, 170 feet of Kirklinton Sandstone were found, resting on that of St. Bees. It also forms the cliff at Rockcliff on the lower Eden. Higher up the Esk it is seen beneath Longtown Bridge, and at various spots in the river-bank opposite Netherby; and it is well displayed in the sides of the beautiful gorge, in which Carwinley Burn flows, between Carwinley Mill and its outfall into the Esk.

The Kirklinton Sandstone, besides being of a much brighter colour than the St. Bees, is a very false-bedded rock, and so uniformly soft that it is scarcely ever quarried. Indeed, I can only remember one place where it is hewn for building purposes, and that is on the Line between Shield Green and Kirklinton Hall, where a harder band appears to be interbedded with it. In this harder band, which may be 30 feet or more in thickness, are two quarries, one in the northern corner of Hirst Wood, the other at Stag Ford, about 500 yards away. In the neighbouring Hetherburn no quarries are seen between Cliff Bridge and Hether Bank Bridge, where the Kirklinton Sandstone is at the surface, while they abound above Hether Bank Bridge, where the St. Bees Sandstone appears.

Two outliers of Kirklinton Sandstone exist. One rests on Carboniferous rocks opposite Canobie Church, on the Scottish side of the Border; the second is on the Cambeck, near Walton, and lies upon St. Bees Sandstone.

We may now consider what evidence there is pointing to an unconformity between the Kirklinton and St. Bees Sandstones. Six or seven miles south-east of Carlisle Mr. Goodchild estimates

the thickness of the St. Bees Sandstone at from 1,500 to 2,000 feet; and its thickness at and around Brampton can hardly be less. It is also very thick between the Sark and the Annan Water, on the northern side of the Solway, and between Maryport and the Caldew. But at Hethersgill there can scarcely be more than 800 feet of St. Bees Sandstone, and in Carwinley Burn, where its full thickness is also seen, there are only about 250 feet of it. Both at Hethersgill and in Carwinley Burn there is an almost continuous series of sections, and there are no signs of faults. Thus not only are the Gypseous Shales (found to be at least 142 feet thick at Great Orton) wanting towards the north-eastern end of the Basin, but a very large proportion of the St. Bees Sandstone has also disappeared in that quarter, though both about Brampton on the one side, and between the Sark and Annan Water on the other, it is extremely thick. These considerations seem to me to point to a very decided unconformity between the Sandstones of Kirklinton and St. Bees.

I have preferred the name Kirklinton Sandstone to any other for the rock we have just been considering, because in that quarter only are its relations with the beds both above and below it observable. In addition, the river Line, though from Cliff Bridge upwards one of the most picturesque and geologically interesting of Cumberland streams, is singularly little known. Even the late Prof. Harkness, whose knowledge of Cumberland geological sections was exceedingly extensive, had never visited the Line before the year 1876, and was then much surprised to find out how much there was worth seeing in a quarter he had never previously thought of visiting.

The Stanwix Marls, so-called because they appear at the base of the river-cliff of the Eden, at Etterby Scaur, in that parish, may be seen lower down the river between the North British Railway Bridge and Grinsdale, and again about Beaumont, on the left bank of the stream. Their junction with the underlying Kirklinton Sandstone is visible close to Westlinton Bridge, on the eastern side, and also in two places close to Cliff Bridge; and the Marls themselves may be seen here and there in the little streams which unite and fall into the Line between Low Alstonby and Westlinton, nearly as far eastward as Stonystonerigg.

There is no evidence to determine how far they may extend south of the Eden at Beaumont; but they seem to be very thin at Carlisle. They evidently rest unconformably on the Kirklinton Sandstone. North of the Eden at Carlisle I have seen them as far to the east as the high bank in Rickerby Park, near the road between Carlisle and Low Crosby, and about as far away as the first milestone. South of the Eden at Carlisle I once saw a few feet of shales in an excavation at the foot of Gaol Brow; but elsewhere I have seen nothing but more or less decomposed material resembling the Marls, and never the rock itself in place. In the Carlisle Water-Works Extension on Stony Holme in 1886 (for sections of which I am indebted to the kindness of Mr. R. S. Ferguson) red sandstone was found below river-deposits. The Marls were not found in the deep wells of Messrs. Carr, Caldewgate, and Messrs. Dixon, West Tower Street, and three new railway-bridges over the Caldew, made twelve or thirteen years ago, the lowest of which is close to the junction of the North British and Caledonian Railways, are all based on the underlying sandstone, the Stanwix Marls not having been seen. West of the Caldew there is little evidence; but Mr. E. W. Binney records that at the pumping-engine for the canal by Edenside, which was close to the North British Railway-Bridge, and at a spot where the Marls form the base of the river-cliff, there was a section "which distinctly showed the Marls at the top passing down into the red sandstone below." Mr. R. B. Brockbank also informed me that he used at one time to bathe in a long pool just below this spot. The sides of this pool consisted

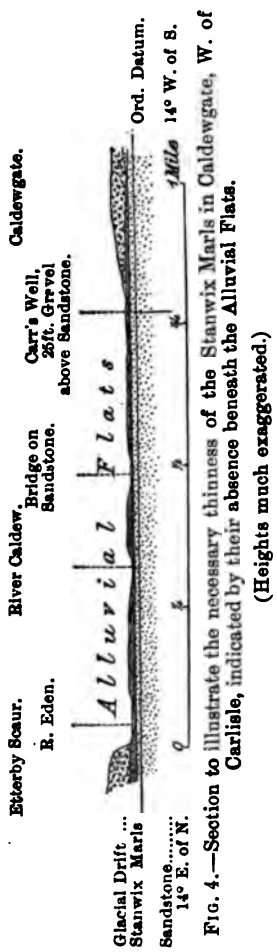


FIG. 4.—Section to illustrate the necessary thinness of the Stanwix Marls in Caldewgate, W. of Carlisle, indicated by their absence beneath the Alluvial Flats.
(Heights much exaggerated.)

of ledges of rock ranging parallel with the line of the cliff, and which, being from one foot six inches to two feet in depth, could hardly have been made by anything but the underlying sandstone.

The whole of the available evidence, therefore, points towards these conclusions:—

That at, and more than a mile west of Carlisle, the Stanwix Marls are extremely thin, their out-crop, below the Drift, being probably a nearly east and west line, either through or a little north of Newtown. Therefore it is highly improbable that they underlie the Lias, except towards its north-eastern boundary. (See Fig. 4.)

The Stanwix Marls at Carlisle appear to be unaffected by any considerable fault, none being known but that which brings them in on the eastern side of Skewbank. If prolonged southward this one points towards a spot close to the North British Railway-Bridge, where the Marls (which are known to be very thin there) appear to be somewhat disturbed. Nor are there any signs of faults in the Caldew Valley between Carlisle and Cummersdale.

The Lias, where it is visible, appears to consist of dark shale with limestone bands. It is probable that the boring near Great Orton, already mentioned, which showed 210 feet of Liassic beds below 18 feet of Drift, gave also the maximum thickness it attains, as the ground reaches its highest level on the Lias plateau in that neighbourhood, which is very near its centre. The best section in the Lias is in a brook between Great Orton and Flat. It is also visible to a very slight extent in Thornby Brook, and at Quarry Gill, near Aikton. It was at one time supposed to be Carboniferous rock, the result of the existence of an anticlinal, but Mr. R. B. Brockbank found ammonites and other Lias fossils in it. He sent them to Mr. E. W. Binney, who pronounced them Liassic, and soon after visited the district and described it in the 'Quarterly Journal of the Geological Society,' Vol. xv. *Ammonites johnstoni* was found at each of the three places mentioned, a fact which indicates that it probably occurs throughout the mass. This ammonite belongs to the zone of *Ammonites planorbis*, the lowest of the Lower Lias.

Whether Rhætic Beds exist or not is a question which may

perhaps never be decided in this drift-covered, sectionless district. No evidence of any has yet been seen.

From the available evidence, which unquestionably leaves much to be desired, it would appear that this outlier of Lower Lias rests unconformably, partly on the Gypseous Shales, partly on the Kirklinton Sandstone, and partly on the Stanwix Marls.

The country occupied by the Lias outlier is so awkward to get at, the sections are so few and so extremely small, and the district generally so wanting in beauty and interest, that no excursion to it has been planned.

Before passing on from this part of my subject to the Superficial Beds, a question of considerable importance concerning the relations of the Permian-Triassic and Liassic rocks to each other demands attention. I have in the preceding pages simply given you my own views as to those relations, stating what the available evidence amounted to, and accepting it as the only possible guide; but some years ago I became aware that my conclusion that the Lias rested unconformably partly on the Gypseous Shales, partly on the Kirklinton Sandstone, and partly on the Stanwix Marls, was deemed so startlingly improbable on theoretical grounds by Messrs. Bristow and Aveline that the publication of Sheet 107 S.E. had been suspended for a time in order that other interpretations might be carefully considered, and possibly additional evidence procured. Though fully recognizing the scanty nature of the evidence which had sometimes decided my view this way or that way, I have from time to time protested against certain modifications, on the ground that, whether the local evidence were much or little, we were unquestionably bound to follow it as regards the map, though a chapter in a memoir might well be devoted to the consideration of alternative interpretations. As I now find that the Carlisle quarter sheet (107 S.E.) is on the eve of publication, "with modifications by W. T. Aveline," and as these modifications are entirely based upon the supposed necessity of showing the Lias resting conformably on the Stanwix Marls, I propose to consider briefly, first, the supposed theoretical necessity for these modifications, and, secondly, their practical results.

I am, in the first place, utterly at a loss to understand how

we can expect any series of strata to be found resting invariably on any other given series, inasmuch as it is practically impossible that they can be conterminate. In the case of the Permian-Triassic rocks we have a series of beds which are generally admitted to have been deposited in great lakes, which have varied both in area and in freshness or saltness from time to time. We find accordingly, as might be expected, a great number of local variations and unconformities in this series, which often make it impossible to speak with certainty as to the correspondence of subdivisions in one district with those in another. Mr. H. B. Woodward, in his paper on "The Permian and Trias" ('Geol. Mag.,' Sept., 1874), writes as follows:—

"Thus it will be seen that there is no very strong evidence for a great break in the Triassic series throughout the British area, but that locally in them, as in the Permian series, there were pauses in deposition, accompanied by some erosion of the beds."

"Pauses in deposition, accompanied by some erosion of the beds," are precisely what we have in the Carlisle Basin. It seems to me evident that the Lower Lias—a marine, shallow-water formation—must naturally be expected to overlie the Trias at these local centres of erosion, as well as elsewhere; and because there are large areas without any local centres of erosion, where the Lower Lias is found lying apparently conformably above the Trias, this furnishes no presumption against the existence of areas where local erosion prevents a similar state of things. Indeed, when we consider the lacustrine origin of the Permian-Trias, and the marine origin of the Lias, it is almost absolutely certain that such local unconformities between them must occur here and there. Therefore it seems to me that the conformity or unconformity of the Lias to the Trias in any given area is a perfectly open question, to be decided in each case by the careful and impartial weighing of the local evidence.

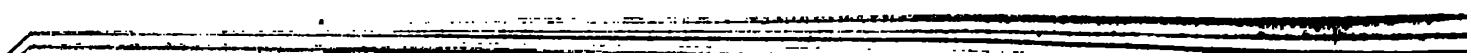
So much, then, for the supposed necessity which has prompted geologists so experienced and respected to make these modifications. I will now proceed to discuss their nature.

The slight amount of evidence in some places, and the utter absence of any in others, allows a singular amount of latitude in this case. It may be remembered that with regard to the

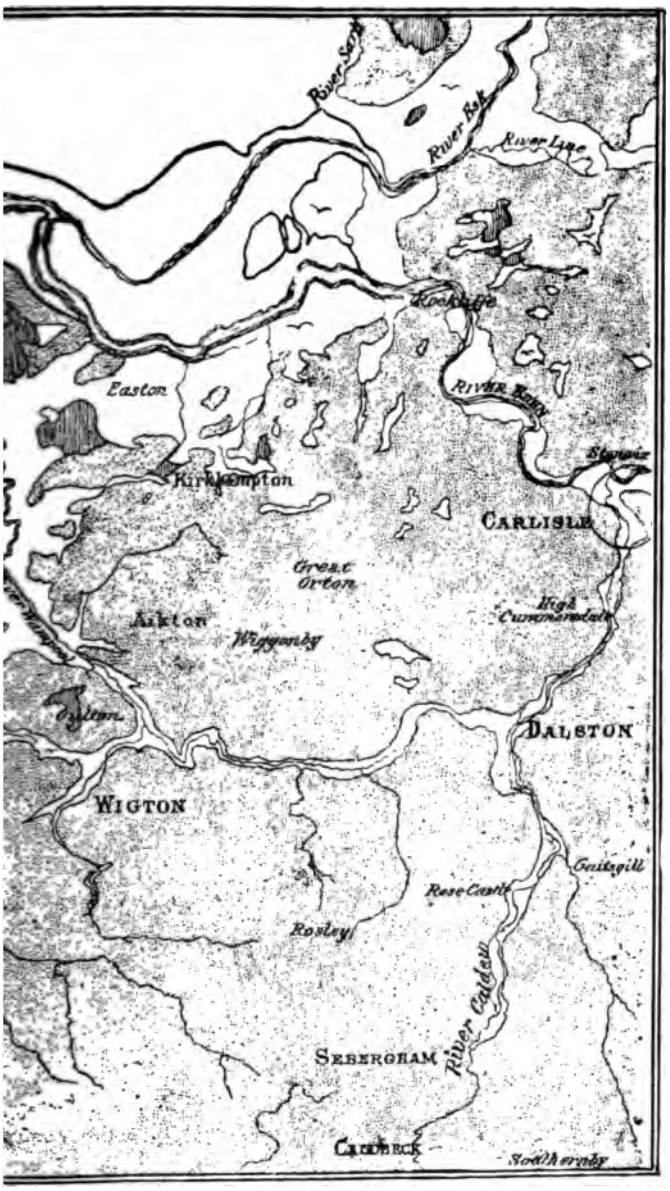
Gypseous Shales, known only by borings at Abbey Town, Bowness, and Orton, I remarked that they rested directly upon the St. Bees Sandstone, west of the Lias, while the Kirklinton Sandstone did so east of that formation; and that I considered the Gypseous Shales the earlier in date, because there was no evidence that they were lying unconformably on the St. Bees Sandstone, while there was a fair amount showing that the Kirklinton Sandstone did so. For in Carwinley Burn not only were there no Gypseous Shales, but most of the St. Bees Sandstone had also disappeared. In treating of the Stanwix Marls I pointed out that they were seen lying on the Kirklinton Sandstone at Cliff Bridge and elsewhere, and showed that at and west of Carlisle the evidence demonstrated that they were exceedingly thin, and extended but a very slight distance south of the Eden.

The modifications are these. By treating the Kirklinton Sandstone as simply the upper beds of the St. Bees, and by identifying the Gypseous Shales with the Stanwix Marls, the Lias is seen reposing conformably on the united Gypseous Shales and Stanwix Marls; while, in order to account for the identification of the two, a fault is introduced, bounding the Lias at its northern end, ranging in a north-west and south-east direction, and having a downthrow to the south-west. By this fault the Lias and an increased thickness of the Stanwix Marls are both brought in, together with, apparently, the gypseous material in which the Stanwix Marls northward are deficient. About Carlisle the Stanwix Marls are shown stretching southward to a very much greater extent than the evidence warrants, while on the Beaumont side they spread out to Bowness.

It may be granted that there is a bare possibility that the St. Bees and Kirklinton Sandstones may be one, without any unconformity between them, but probability seems to me to be decidedly against it. The Stanwix Marls may also be the Gypseous Shales with almost all the Gypsum left out, but nobody would suppose them to be identical but for theoretical prepossessions. The Stanwix Marls may also, after appearing to be very thin west of Carlisle, suddenly thicken out in the extraordinary way depicted, but it is highly improbable that they do so. Lastly, any scheme which demands, in addition, the




MAP TO ILLUSTRATE
THE PHYSICAL GEOGRAPHY OF NORTH WEST CUMBERLAND
By T.V. Holmes F.G.S
Scale Three Miles to an Inch.
RAISED BEACH AND BLOWN SAND
PEAT.
ALLUVIUM AND RIVER GRAVEL
GLACIAL DRIFTS AND ROCKS UNDERLYING THEM
SILLOTH BAY
Calvo
Abbey Town
Dubmill Point
Brayton Hall
ALLONBY BAY
Allonby
Aspatria
River Ellen
Plumbland


River Esk
River Eden
River Line
Rockcliffe
Easton
River Petteril
Kirkbampton
CARLISLE
Great Orton
Aikton
Wiggonby
High Cummersdale
Oulton
DALSTON
WIGTON
Gaitsgill
Rose Castle
Rosley
River Caldew
SEBERGHAM
CALDBECK
Southwaite

existence of a great fault, for which there is no evidence whatever, appears to me to be self-condemned. For though, as at Catlands Hill, a fault which is nowhere seen may have its existence made manifest through the juxtaposition of certain beds, which but for it would necessarily be far apart, the invention of a fault where there is no evidence of one, simply in order to obtain a result in harmony with theoretical prepossessions, is, it seems to me, an utterly unsound and unscientific proceeding. It is, therefore, because it appears to me that a map should faithfully reflect the evidence of a district, whether conclusive or inconclusive, and because a different view appears to be held by many geologists of high character and eminence, that I deem it my duty, on this matter of scientific principle, to trouble you with this protest.

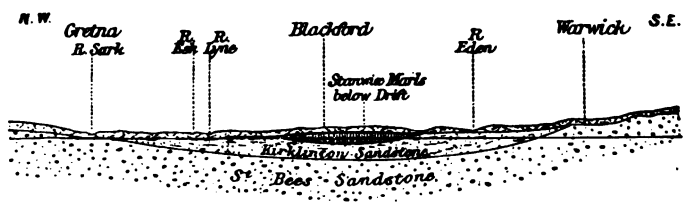


Fig. 5.—Section across the Carlisle Basin from Gretna to Warwick.

III.—The Superficial Beds.

Of the superficial beds the oldest and most important are those known collectively as the Glacial Drift. These beds vary a good deal in composition. The clay known as Till, in which stones of many kinds are mixed confusedly, is not often seen, except on the high ground occupied by the Lower Carboniferous rocks. Nearer the Solway the Glacial Drift appears to thicken, and it certainly covers the surface more uniformly. (See Map, Fig. 6, and Diagram-section, Fig. 7.) Thus, north of the Maryport and Carlisle Railway the only piece of ground of any appreciable size bare, or almost bare, of Drift is a tract of about one square mile between Aspatria and West Newton, in which there are many quarries in St. Bees Sandstone. A bore-hole made 14 or 15 years ago near Abbey Town revealed a thickness of nearly 200ft. of Drift, and, though this thickness may perhaps be exceptional, streams flowing in gorges of 30ft.

or more in depth often show nothing but Drift, and so do railway-cuttings of similar size. In short, the evidence of railway-cuttings, streams, and farmhouse wells tends to show that north of the Maryport and Carlisle Railway the Drift is usually more than 30ft. thick; and outside that area the amount of surface in which Carboniferous or Permian-Triassic rocks appear is very small, though it increases as we approach the Carboniferous Limestone fells.



FIG. 7.—DIAGRAM-SECTION ACROSS NORTH-WEST CUMBERLAND
To show the Order of the Superficial Deposits

Below the fells it soon becomes evident not only that the surface of the ground is almost wholly covered by Glacial Drift, but that the features noticeable are Drift ridges, owing nothing of their shape to the underlying formations. Sometimes over large areas we find regular undulations almost perfectly parallel to each other. In other places these are not so clearly marked, though the contours of the ground testify to the presence of uniformly soft strata. The only spot within the Permian-Trias area where the influence of the underlying rock is manifest in the shape of the ground is where the Lias outlier appears. This outlier is very uniformly covered by Drift, though it is not so thick there as on the lower ground outside it; but the geologist standing at Wiggonby, on the southern edge of the Lias outlier, will see northward of him land of flattened, plateau-like contour, while to the

south he views a country of undulating ridges resembling those in areas westward, where nothing but Glacial Drift can be seen. A well-sinker, living in this district a little southward of the Lias, told me that he had never met with anything in that neighbourhood but sand, gravel, and clay, though he had sunk to depths of 20, 30, and 40 feet in many spots thereabouts.

Good sections in these Glacial Drift beds are very rare, the best I have ever seen having been in the neighbourhood of Carlisle, some years ago, when a great extension of railway-sidings was taking place on the completion of the Midland Line from Settle to Carlisle. The changes in the nature of the beds as the excavations widened were very curious. What had seemed more Till-like than usual one week looked next week more like earthy gravel, and in a third week like sand and gravel, or *vice versâ*. Nests of Till were seen here and there in the midst of sections of gravel. On the whole, the most extensively diffused form of Glacial Drift is what may be styled Earthy Gravel.

Here and there, however, rising above the ordinary Drift-ridges, mainly consisting of Earthy Gravel, are mounds and ridges of clean sand and sandy gravel, which, though they do not occupy any large proportion of the surface, except in certain limited localities, are often very conspicuous where they do appear. These Eskers abound on both sides of the Solway. North of the estuary they may be seen at Cummertrees, and north of the town of Dumfries. In Cumberland the Newcastle and Carlisle Railway crosses an Esker tract between Heads Nook and Brampton, and another exists about halfway between Abbey Town and Allonby. A little group of Esker ridges appears near Crofton Hall, the most prominent of which is a beautifully wooded hill, known as Torkin, which we may perhaps see on the day of our Chalk Beck Excursion, together with a slight ridge south of Dalston Hall. These Eskers, where a section can be seen, look as if they had been heaped up irregularly by marine action. Many hollows which have no outlet exist here and there in the midst of an Esker tract. Whether they occur massed together with outlying mounds and ridges, or simply as isolated ridges, they contrast very much, in their irregularity and boldness of outline, with the regular undula-

tions of the Earthy Gravel. The Eskers, of which Torkin is the most conspicuous, are a group of isolated ridges. See Fig. 8.

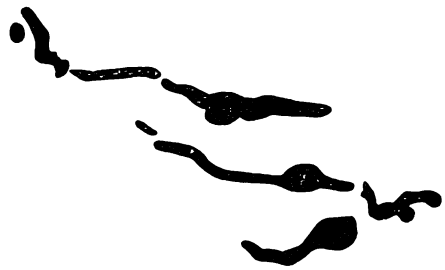


FIG. 8.—Eskers, Crofton Hall. (From the 'Geological Magazine,' 1883, p. 440, by kind permission of Dr. Woodward.)

The contrast between the contours of ground occupied by ordinary Glacial Drift and those of an Esker district may be easily seen during the course of a railway journey from Carlisle to Brampton. Between Carlisle and Heads Nook the journey is through a country covered with Glacial Drift of the ordinary type, the contours of the ground being flattened, uniform, and regular. East of Heads Nook we see steep, irregular mounds and ridges, with here and there, in the midst of them, peaty hollows. The tract between Abbey Town and Allonby presents the same general characteristics as that of Brampton, but the Eskers are of somewhat smaller size. East of Brampton, Eskers may be seen up to a height of 700ft. or more, while near Abbey Town the highest only attains a height above the sea of 156ft., though they form the highest ground in that district.

Eskers are found at very various levels, from that of the Raised Beach to a height of 800 feet. Many are scattered here and there between Kirklinton and Brampton, and a ridge south of Arthuret Church may be seen during our visit to the Kirklinton district. As regards their formation, my own opinion is this. Towards the close of the Glacial Period the whole area was submerged beneath the sea, till ground now 800 feet above it was brought beneath its level. During the submergence much of the Till or Boulder Clay would be converted into gravel more or less earthy. On the emergence of the district much of this earthy gravel would be entirely removed, and

much earthy and clayey matter washed out of part of the rest. This clean, sandy gravel and sand would be here and there heaped up into Esker mounds and ridges, which were, at the time they were formed, analogous in position to the various bars and sandbanks now being heaped up off our coasts. Some persons may ask why subaërial denudation has had so little effect on their forms since the date of their formation, but a little reflection will show that there is no great mystery in the matter. If—to take an illustration from the London District—we inquire why the Lower Tertiary escarpment between Greenwich and Erith is so deeply hollowed out by combes, the answer is obvious. Below the thick mass of Blackheath Pebble-beds capping the escarpment, are the Woolwich Series, which contain thin clayey bands. These hold up the water which percolates freely through the Pebble-beds, and cause its exit in springs here and there along the hillside. Of course the influence of rain on a slope, where this undermining action of springs has been going on for ages, has been most potent, and has produced the remarkable sculpturing of the surface we now see along the course of this escarpment. But in the case of Esker ridges no springs are at work, the whole mass being thoroughly permeable from top to bottom, and resting on more or less permeable strata below; and as, in addition, they contained no soluble calcareous matter, and were probably speedily covered by grass or other vegetation on their emergence, there is no reason why they should not have remained for ages almost entirely unaffected by subaërial denudation.

Before leaving the subject of Eskers it may be well to point out that they are known to exist on the west coast of South America in the desert of Atacama, where neither rain nor rivers can have had any influence on them. My cousin, Mr J. J. Winder, who has been long resident in South America, and to whom I am indebted for information about them, remarks:—"That they are true Eskers can hardly be doubted, as in some places where sections exist the shingle is clearly to be seen heaped up as though by the force of opposing currents." These Esker ridges sometimes rise to a height of more than 200 feet above the plain on which they lie.*

* See "On Eskers or Kames," 'Geol. Mag.,' Oct., 1883.

The peat-mosses in one respect form a connecting link between the Glacial Drift and the river-terraces and alluvial flats, inasmuch as they appear at various levels, sometimes lying in hollows on the Glacial Drift, sometimes being found on the great estuarine flats which border the Solway, as though they rested upon portions of them. These mosses are usually highest in the centre, so as to form a very low dome. Among those on the Earthy Gravel are Bolton Fell, near Hethersgill, Scaleby, Solway, and Oulton Mosses. Oulton Moss, near Wigton, occupies the greater part of the site of a small lake, only a small part of which remains unfilled by peat. Old maps also show a lake near Cardurnock, at the south-western end of the large peat-moss which occupies the greater part of the Bowness peninsula. Diligent search in these last-named localities might, perhaps, reward the investigator of ancient lake-dwellings.

Besides the mosses already named, there are Drumburgh Moss, Wedholme Flow, that drained by Holme Dub and Black Dub, and some others.

A glance at the alluvial flats of the various streams, from the Caldew westward, shows that the rivers of this district have been in the habit of changing their courses from time to time, as the flats communicate with each other in the strangest way. If we take the Caldew, for example, we find that it now flows nearly due northward into the Eden at Carlisle; but at Dalston there is evidence in the flat of river-gravel which forms the water-parting between its present course and that pursued by the various streams which run westward into the Wampool, that the Caldew once, when flowing at a somewhat higher level, took a westerly turn at Dalston instead of a northerly one. There is a similar connection between the flats of the Wampool and the Waver, north of Wigton; and though we can walk from Abbey Town to Allonby on what seems to be one continuous alluvial flat, whether peaty or not, we find that while Holme Dub flows northward into the Waver at Abbey Town, Black Dub discharges itself into the sea at Allonby. If we look at the great low-lying peat-mosses and their distribution, and also note the amount of more or less peaty soil outside the area that can fairly be called peat, it be-

comes evident that these peat-mosses were once considerably larger than they now are, and that changes in the courses of the rivers may have done much to diminish their size. For example, Bowness and Drumburgh Mosses were once probably continuous, but have been separated either when the Eden took a south-westerly course towards Kirkbride, or the Wampool a north-easterly one towards Easton.

The most interesting peat-moss historically is Solway Moss, situated in what used to be known as the Debateable Land, the country between the rivers Esk and Sark. Close to it occurred the surprise and rout of the Scottish army in 1543, when many of the fugitives were lost in its treacherous depths. On the night of November 16th, 1771, Solway Moss burst, and, flowing over the edge of the elevated ground on which it rests, covered 500 acres of the broad alluvial plain of the Esk. No human lives were lost, but many cattle were destroyed. (See Hutchinson's 'History of Cumberland,' Vol. ii, p. 542.)

There are many small peat-mosses north of Carlisle, between the Eden and the Esk and Line. No lakelets are now found there, though some which once existed have been drained, and are now represented by alluvial flats. The turnpike road between Carlisle and Gretna crosses many of them. This network of what were once either lakes or morasses must formerly have given much additional strength to the Border City. Hutchinson, writing a century ago, records the existence of a small lake in the parish of Rockcliff.

The large peat-moss known as Wedholme Flow is situated in the parish of Holm Cultram or Abbey Town. Of this parish Hutchinson records:—"There is little wood, except a few trees about the dwelling-houses;" but we learn that in the time of Queen Elizabeth it was enacted that the tenants of the manor were to have the wood growing in Wedholm Wood for the repair of the sea-dykes Perhaps the cutting down of trees for this purpose may have led to the blowing down of large numbers of the others during storms. This would obstruct the drainage, and give rise to a morass in which trees would not grow, but which would be highly favourable to the growth of peat-moss. Hence possibly, as in so many other cases, the

total disappearance of Wedholme Wood, in spite of provision to ensure "the better preservation of the woods," and the enlargement of Wedholme Flow.

As regards the existence of submerged forests or peat-mosses in the Solway, Camden remarks of Bowness:—"That the figure of the coast hereabouts has been altered, appears plainly from the roots of trees, covered over with sand, at a good distance from the shore, which are often discovered when the tide is driven back by strong winds." On inquiring in 1880 of Mr. R. B. Brockbank as to whether any submerged forest had been recently visible, he replied:—

"I found an intelligent old man, Robert Johnston, who told me that fifteen or sixteen years ago the channel, which shifts about very much in cutting its way into the sand, formed a steep bank on one side, on the edge of the wide flat of sand which stretches away from Cardurnock towards Criffel, and laid bare three or four feet of peat, below five or six feet of sand." Wood was found embedded in this peat. But the channel, when Mr. Brockbank wrote, had again shifted, and nothing could then be seen but an unbroken sandy flat.

A slightly elevated Raised Beach, often more or less covered by Blown Sand, extends from Bowness to and beyond Cardurnock. Crossing the estuary of the Waver and Wampool, we find Skinburness, Silloth, and Allonby all situated upon it, and it extends some distance southward of them. Thus we have in this district evidence both of geologically recent upheaval and of subsidence. The probability is that the upheaval of the raised beach elevated the land to a somewhat greater height than it now has, and that a slight subsidence has since occurred, and reduced the district to its present level.

Where the Raised Beach can be seen unobscured by Blown Sand, the shingle ridges of which it consists may be observed ranging in a direction nearly parallel with that of the present coast-line. At Campfield, two miles west of Bowness, two of these ridges, more strictly parallel to each other, and sharper in outline than usual, deceived the Ordnance surveyors into a belief in their artificial origin, and caused them to draw two connecting lines at right angles to these ridges, and to add the

words, "site of camp." However, the geological visitor will have little difficulty in seeing that the northern and southern sides of the supposed camp are really natural shingle digers, and that there are no signs whatever of any ridges connecting them. Mr. R. S. Ferguson, of Carlisle, remarked of some exploratory diggings carried on there in 1880 that they revealed nothing to indicate the Romans, and nothing to indicate a camp, but the name.

But of all formations the Eskers offer by far the most likely field of controversy between antiquarians and geologists. For sometimes (as in the case of Torkin) an obscure Esker ridge swells out so suddenly both in height and breadth as to be calculated to deceive the most careful observer for a time. In other places isolated Esker mounds present the appearance of large tumuli. On the other hand, a natural tumulus may well have been looked upon as a suitable spot for the interment of a chief in prehistoric times. Yet no evidence of such burial might reward the explorer of our days, as the highly permeable Esker sand and gravel would allow the removal, by the action of rain-water, of everything but stone implements and pottery fragments.

Before concluding, I must not omit some remarks on the changes perpetually taking place in the channels of the Solway, and their consequences. The chief channel is that resulting from the union of the rivers Esk and Eden, but the position of this junction and that of the united channel is perpetually varying. This has caused a rapidity of growth and decay in certain ports on the Solway which has probably not been equalled anywhere else on our shores. For example, in 1301 Skinburness was a port of some consequence, having been a chief place for the King's magazines when expeditions against Scotland were taking place. It was accordingly made a free borough by King Edward I. But in 1305 the Abbot of Holm Cultram applied for leave to have a market and fair at Kirby Joan (now Newton Arlosh) instead, and in the grant made in consequence of that petition it is stated:—

"That the abbot had reported that a great part of the road leading to the borough (of Skinburness), and much of the borough itself, by divers invasions and storms were wasted; and that the inlets of the sea were become so deep that people

could not resort hither, or inhabit the place, as before, on which account the abbot had petitioned that the village of Kirby Joan should be created a borough, with the like liberties and privileges as Skinburnesse had before held."

A change in the direction of the chief channel of the Solway, which should restore the state of things existing in the year 1840, would give Skinburness the same advantages over neighbouring places which it possessed in the year 1301. The deep channel close to the town in King Edward's time probably came at last to eat into the soft materials of which the shore is composed, while its existence would enable the sea to act with much greater force on the coast thereabouts during storms. Hence the suddenness of the destruction of the rising port. The road leading to it must have been along the raised beach close to the shore, on which the road between Skinburness and Maryport now lies. From Old Mawbray northward the Raised Beach has marshy ground on the land side, which would have been very unsuitable for a road; and the Romans doubtless connected their camps at Moresby, Maryport, and Beckfoot by means of a road along the Raised Beach. It seems almost certain that this road would be continued northward as far as Grune Point, and by no means improbable that it was thence connected with another from Cardurnock to Bowness by means of a causeway which would give a safe passage at low tide. Camden (quoted by Hutchinson, Vol. ii, p. 485) says of Bowness:—

"The inhabitants at this day called it Bulness; and though it is but a very small village, yet it has a fort, and (as a testimony of its antiquity) besides the tracks of streets and pieces of old walls, it has a harbour, now choaked up, and they tell you that a paved causeway ran along the shore from thence as far as Ellenborough."

But while the remains of mediæval Skinburness are to be looked for under the present foreshore, a very different fate has been that of Port Carlisle, about a mile east of Bowness. As its name implies, it was intended that it should form the port for Carlisle; a canal was made between the two places, and opened in 1823; but the Solway channels, favourable when the canal was being made, speedily altered their position, and

the harbour became silted up. The canal became the site of a railway in 1854, and in 1856 this railway was continued from Drumburgh to Silloth, the newest of the Solway ports, about one and a half miles south of Skinburness. The first dock at Silloth was constructed in 1857, and another has recently been made there. The 'Carlisle Journal' of April 1st, 1881, contained an interesting paragraph on a 'Change in the Channel at Silloth,' in which it is stated:—

"The bed of the channel near Silloth jetty is gradually returning to the position it occupied when the Silloth Dock was formed. . . . Very soon after the dock was formed the channel commenced to recede from the jetty. It continued to recede, the sand accumulating at the end of the pier to the height of 20ft. There had been a depth of 16ft. of water at this point, and the alteration in the bed of the channel created inconvenience to steamboats in landing passengers. A dredger was employed in keeping open the channel. About two months ago it became evident that another change had set in, the accumulation of sand at the end of the jetty appearing to be getting less. Since that the sand has been gradually cleared away, and now there is again 16ft. of water at the jetty end, enabling steam-boats to land passengers there at all times of the tide."

Let us hope that Silloth, unlike its predecessors, Port Carlisle and Skinburness, is destined to

Suffer a sea-change
Into something *rich* and strange.

An Outline of the Geological History of the Eden Valley or Edenside.

By J. G. Goodchild, F.G.S.

Compiled from various published sources of information, and communicated to the Association by permission of the Director-General of the Geological Survey.

(*Read July 5th, 1889.*)

The geology of the parts of the "Eden Valley"* to be visited during the Long Excursion of 1889 is so varied, and, in many of its details, so complicated in structure, that the comprehension of some of even the broader features will hardly be possible without some kind of conspectus of the history of the rocks as a whole. When the outlines of the history of each formation have been mastered it will be a comparatively easy task to comprehend their inter-relations in the field, and to understand the long series of changes that have ultimately led to the appearance of the several rocks at the surface in their present positions.

The distribution of the several formations is shown in a generalized way on the small geological map, Fig. 1. Their stratigraphical relations are shown to some extent by Fig. 2, which passes across the Lake District from south to north.†

The general character of the surface relief is seen by reference to the contoured map at the end. (Fig. 17).

The following table shows the general succession of the rocks in descending order, together with the positions and proportions of the principal breaks in the strata:—

Various forms of Recent and Glacial Deposits.

Oligocene Dykes.

? Remains of Cretaceous Rocks off the West Cumberland Coast.

* It is better to employ the old name Edenside for this district between the Lake District and the Pennine Escarpment.

† Lent by Mr. H. B. Woodward.



Unconformity. Position of Third Plain. Break of several thousand feet.

JURASSIC ROCKS.

NEW RED (4,000 feet).

(*a*) Upper New Red—(1) Stanwix Marls, etc., (2) Kirklinton, St. Bees', etc., Sandstones, (3) Lower Marls.

(*b*) Magnesian Limestone and Plant Beds.

(*c*) Penrith Sandstone and the Brockrams.

Great Unconformity. Position of Second Plain. Break of two miles or more.

CARBONIFEROUS ROCKS (7,000-12,000 feet).

(*a*) (1) Coal Measures, (2) Millstone Grit.

(*b*) (1) Yoredale Rocks, (2) Mountain Limestone, including the Calciferous Sandstone and the Roman Fell Beds.

(*c*) Upper Old Red.

Great Unconformity. Position of the First Plain. Break of five to six miles.

? MIDDLE OLD RED.

Break of undetermined extent.

SILURIAN ROCKS (10,000 to 14,000) feet.

A (*a*) Kirby Moor Flags (Ludlow). 2,000 feet.

(*b*) Bannisdale Slates (Ludlow and Wenlock in part.) 5,200 feet.

(*c*) Coniston Grits and Flags (Wenlock Shale). 6,200 feet.

B (*a*) Pale Slates. 500 feet.

(*b*) Graptolitic Mudstone, and Cautla Conglomerates. Break.

ORDOVICIAN, Lower Silurian, or Upper Cambrian. (20,000 feet).

(*a*) Bala Sedimentary and Volcanic Rocks.

(*b*) Borradale Series, together with the contemporaneous Milburn Rocks and the Ingleton Green Slate Series.

(*c*) Skidda Slates (older part).

Various rocks of Plutonic and Metamorphic origin.

I.—Older Palæozoic Rocks.

Taking these rocks in chronological order we come first to the Skidda Slates. These consist of a pile, from ten to twelve thousand feet or more in thickness, of alternations of thin argillites, flags, and sandstone, with a few beds of conglomerate. The whole series is of marine origin.

The fauna, on the one hand, and the stratigraphical evidence on the other, point to these rocks as the equivalents in time of the Welsh strata from the Llandeilo rocks down to, possibly, the Lingula Flags. The fossils include many forms of graptolites of Ordovician types, together with a peculiar assemblage of trilobites, phyllopods, brachiopods, and some mollusca proper. The rocks exhibit a very remarkable uniformity of lithological character in both their horizontal and their vertical extent.

Locally, contact-metamorphism has converted the argillaceous members of the series into andalusite-schists, while the arenaceous strata have passed into the condition of mica-schist. South of an east and west line through Cross Fell the argillaceous members of these (and of the other Siluro-Cambrians) are affected by cleavage. To the north of that line cleavage gradually becomes imperceptible.*

During the later part of the Skidda Slate period volcanic eruptions commenced along a zone ranging in a north-easterly direction through where Keswick is now. Lavas, tuffs, and coarse agglomerates, chiefly of an andesitic character at first, accumulated around the vents at a higher rate than that of the local subsidence then in progress, so that the cones, at an early period, extended well above the sea-level; therefore, in the main, these rocks are of subaërial origin. There is reason for believing that the rate of subsidence was not by any means uniform over the whole district, and that, especially in the northern part of the area, elevation and consequent denudation of the Skidda Slates went on contemporaneously with subsidence and the formation of newer rocks in the south.

The main centres of eruption are now mostly buried beneath newer rocks, but one of these old necks, much altered by proximity to another vent of Old Red age, is now represented by the gabbro, etc., of Carrock (Carrick) Fell. The coarser

* 'Geol. Mag.,' II, x, p. 399.

Then, as the paroxysms abated, ordinary sedimentation was again resumed, and beds of Skidda Slate were again deposited. But with further growth of the old volcanoes parasitic cones grew upon their flanks, and the eruptions were thus extended over an increasingly larger area, and a larger proportion of submarine tuffs came to be laid down. The alternations of Skidda Slate and submarine tuffs thus deposited on the eastern flanks of the principal area of eruption I have often referred to as the *Milburn Rocks*, from the village where this type is best exhibited.

By the time the Bala Period had set in the growth of the parasitic cones had extended the subaërial volcanic rocks over an immensely large area, and we accordingly find fossiliferous sedimentary rocks containing Bala types of fossils, interstratified with tuffs and lavas.

The later eruptions seem to have been chiefly rhyolitic in character, though eruptive rocks of an intermediate, or even of a sub-basic type are also represented; but, on the whole, the more ancient volcanic material is of a less acid composition than the newer, instead of the reverse, as is commonly the case.

The foregoing observations will serve to make it clear why the principal volcanic rocks to be examined during the present Excursion belong to the later part of the Borradale Period. While the lower beds of volcanic material were being piled up in the central area there was nothing but ordinary sediment being laid down in the submarine area to the east. It was only when about half the entire thickness had been accumulated in the Lake District that occasional showers of tuff fell as far out to sea as where, say, Milburn now is; and it was not until the old volcanoes had nearly attained their maximum development, which was in the later part of the Bala Period, that the easterly extension of the parasitic cones to this area transported materials in quantity sufficient to preclude the formation of ordinary marine sediment.

As mentioned above, Bala stages of evolution had set in long before the close of the volcanic episode; and the characteristic life-forms of that period flourished in abundance on the old sea-bottom in the intervals between the more violent paroxysms. Even when the nature of the eruptions was such as to drive the animals away for a time, their modified descendants and their

relations returned again and flourished as their ancestors had done before. Some of the beds of limestone formed at this period consist almost entirely of the unworn remains of encrinites, trilobites, brachiopods, and mollusks.

But there were areas around the principal cones that were not submerged until after the last eruptions had ceased. So the Coniston Limestone, as will be seen by a reference to the Geol. Survey maps, 98 N.E. and N.W., was almost the only bed of sedimentary origin that extended across this particular area. The Association will have a good opportunity of comparing with this thin stratum the fine development of Bala Rocks accumulated on the seaward flanks of the old volcanoes. On the S.W. face of Roman Fell these are seen to be many hundreds of feet in thickness, as they are in Craven.

With the Coniston Limestone and its chronological equivalents terminates the last record of Ordovician events in Cumberland and Westmoreland. Continuous subsidence had been going on to a depth of twenty thousand feet or more; and it seems that the time had arrived when movements in the opposite direction began to prevail. Many geologists maintain on good grounds that here, as in Wales and in Craven, the close of the Ordovician period was marked by the advent of considerable disturbance, upheaval, and denudation of the older strata. Whether the rocks of Cumberland and Westmoreland remained unaffected is a point much disputed; but those who have gone over the Craven area with Professor Hughes's memoir* in hand cannot well have much doubt about the magnitude of the disturbances and denudation that ensued there at the time now referred to. At all events, and whatever happened, we find ourselves at this point face to face with one of the most difficult, and therefore one of the most interesting, problems the student of Palæozoic geology has to deal with. The facts are of this kind:—Two kinds of fossiliferous rocks have been herein mentioned so far. The older is the Skidda Slate, which contains a well-marked graptolite fauna, about which there is not much room for dispute; and the newer (locally separated from the older by many thousands of feet of strata) is the Bala series. Graptolites have not hitherto been found in this—presumedly because graptolites required pecu-

* 'Geol. Mag.,' Vol. iv, p. 346.

liar life-conditions which did not happen to obtain in this region during the Bala period. Now the next bed above the Bala beds in Cumberland and Westmoreland is simply crowded with graptolites, and with forms too, be it noted, that palæontologists were wont, not so long since, to refer unhesitatingly to Llandeilo horizons. In other words, a "Llandeilo" graptolite fauna was found in a stratum distinctly overlying another stratum about whose Bala age there could be no doubt.

But the anomaly does not end there. The Graptolitic Mudstone—the bed referred to—is locally unconformable to the beds below, in some cases to a considerable extent. More than that, it clearly and unmistakeably graduates upward into the Silurian Series, of which there can be no doubt that it forms, with its conglomerate, the natural base. The rock itself will be seen during the present Excursion. It consists of dark brown, or sooty mudstones, with somewhat the texture of indurated Fuller's earth; and, as I have mentioned above, is crowded with graptolites. For further details regarding these, and the rock generally, reference should be made to Messrs. Marr and Nicholson's paper in the 'Quarterly Journal of the Geological Society,' November, 1888, p. 654, *et seq.* The Graptolitic Mudstones are not many feet in thickness, and near their top they begin to graduate, by interlamination, into a mass of peculiar pale grey-green, felsitic-looking "mudstones," the so-called Pale Slates. These (except in their darker bands) are unfossiliferous. Near their top the Pale Slates, in their turn, graduate upwards by interlamination into the finely striped dark blue argillites known as the Coniston Flags. Of these we shall see only the base. Above them, in uninterrupted succession, were deposited, over an extensive area, the Coniston Grits, the Bannisdale Slates, and the Kirkby Moor Flags, whose aggregate thickness, from the base of the Graptolitic Mudstone to the highest bed seen, amounts to above twelve thousand feet.

These higher beds are full of interest; but it is only with their base that the Association is at present concerned. The basal Graptolitic Mudstone, as I have said, contains a graptolite fauna that retains much of the peculiar facies of those of Ordovician times. The Mudstones graduate upward insensibly, through the Pale Slates, into the Coniston Flags; while they are

separated from the Ordovician beds below by an unconformity more or less marked. Now the Coniston Flags, as the Association will have an opportunity of seeing, also yield graptolites. In this case, however, these organisms are as clearly Silurian in facies as those occurring in their natural base are Ordovician. What has happened? Clearly we have here a case (not by any means an isolated one) where the breaks in the succession of life do not coincide with the breaks in the succession of the strata. If we listen to our palæontologists we must classify the Graptolitic Mudstones with the Ordovicians; while, if we are guided by the physical evidence alone, then the Graptolitic Mudstones with their Ordovician fauna must go in the same group with the beds above and be classed as Silurian. It will never do to close our eyes to these facts, especially as they do not by any means stand alone. Probably no explanation that may be given will ever prove satisfactory to both geologists and palæontologists alike. One such theory—based upon the assumption that the graptolites of the later fauna were the modified descendants of those living in early Ordovician times; and, further, that graptolites in general, like ammonites in later times, could exist only under conditions that were exceptional—may be given here. When the Ordovician volcanoes broke out graptolites could not of course live in their immediate neighbourhood; but they certainly did not all migrate to a great distance, for *Didymograptus murchisoni*, and others also, may be found quite commonly in the bands of Skidda Slate alternating with the tuffs of the Milburn Rocks. Doubtless an enormous interval of time is represented by the vast thickness (12,000 feet) of the Borradale series. To that we have to add the time required for the formation of the Bala rocks; and again, there is the great interval represented by the gap between the close of the Ordovician and the commencement of the Silurian period. During this time (which may have far exceeded the whole time represented by the British Secondary rocks) the graptolites, generation after generation, migrated from area to area, gradually evolving new forms and eliminating older ones as time went on. In course of time one of the great terrestrial undulations travelling in this direction propagated a downward movement of the earth's crust as far as this. As the depression advanced hither the

migration of the graptolites proceeded *pari passu* with it; and eventually the belated survivors of the Ordovician Rhabdophora reached the spot, whence, millions of years before, their ancestors had been driven by adverse circumstances. For a time they held their own and did well; but the subsidence that ushered in the Graptolitic Mudstones was only the commencement of a great movement that carried the sea-bottom here down to unusually great depths. Deep oceanic conditions prevailed, and the old colony of graptolites either migrated still further, or else it became completely extirpated here. The Pale Slates, if I read their history aright, represent a deposit of oceanic ooze, which must have required many millions of years for its accumulation—long enough to admit of the evolution and the subsequent extinction of two or three successive faunas. After a time the ocean-bed gently rose, thalassic (*i.e.*, infra-littoral) conditions took the place of oceanic, films of impalpable mud, derived from the land, again began to be laid down, and the formation of the Coniston Flags commenced. With the advent of the new conditions graptolites again occupied this station; but this time they migrated from a different zoological province, and, as a consequence, they were different in character from their predecessors on the same spot, and represented a much later stage of evolution than did those that preceded them.

The question is one worthy of the most careful consideration, not only in connection with the rocks under notice, but also in the case of the Middle Old Red in relation to the Upper Old Red and the Carboniferous rocks; or, again, in connection with the Carboniferous fauna in relation to that of the Magnesian Limestone. In all of these the older faunas have survived through the long interval of time represented by important unconformities; and the older forms of life have given place to the newer within the limits of a conformable series of rocks. In other words, in these cases, the stratigraphical and the palæontological breaks do not coincide.

II.—Post Silurian Changes.

After the Silurian ocean-bed had subsided through a depth of twelve thousand feet or more we lose sight of the history of the Lake District for a long time. All we can say is that the rocks,

some time afterwards, were subjected to faulting, disturbance, and denudation enormous in extent. Subsequently they underwent that curious, and, even yet, imperfectly-understood process that resulted in the development of cleavage. The cleavage is not due to the pressure that produced the contortions of the rocks; nor is it due to pressure alone, as we have so often been told is the case. Here, at all events, cleavage is not in any way connected with the flexures of the rocks; but is of later date – Post-Silurian, but Pre-Carboniferous.

III.—Middle Old Red.

After the Siluro-Cambrian rocks of Cumberland and Westmoreland had been consolidated, disturbed, denuded and cleaved, it is more than likely that they were for a time buried up beneath a considerable thickness of the Middle Old Red, which was of mixed lacustrine and volcanic origin, and whose remnants are left, even yet, just beyond the limits of the district, and, possibly, also here and there under the newer deposits of Cumberland itself. The relation of the two sets of rocks to each other and to the Upper Old Red is shown in the diagrams, Figs. 3 and 6.

Probably most of the chief plutonic rocks of Cumberland and Westmoreland date from this Middle Old Red period of volcanic activity, including the granite masses, which are regarded as the deep-seated cores of the Old Red Volcanoes. Also it was at this period that the chief metamorphism of the older rocks was effected.

IV.—Upper Old Red.

After the close of the Middle Old Red period this area was again affected by disturbance and denudation. I believe that it was at this period that the initiation of the Pennine Fault took place. Nearly, or quite, all the previously-formed Old Red was denuded, and part of its remains, whether volcanic or detrital, was worked up anew into shingle. I have long known that the materials of the Upper Old Red in Cumberland and Westmoreland consisted largely of re-sorted conglomerates, partly derived from Scottish areas, partly from Middle Old Red porphyrites, partly (though to but a very small

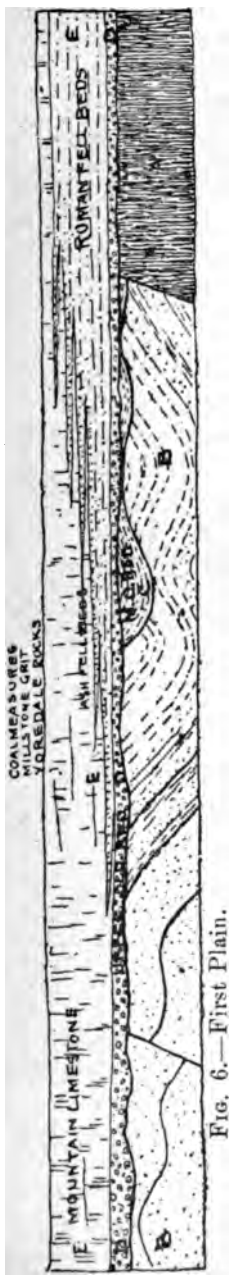


FIG. 6.—First Plain.



FIG. 7.—Second Plain



FIG. 8.—Third Plain.

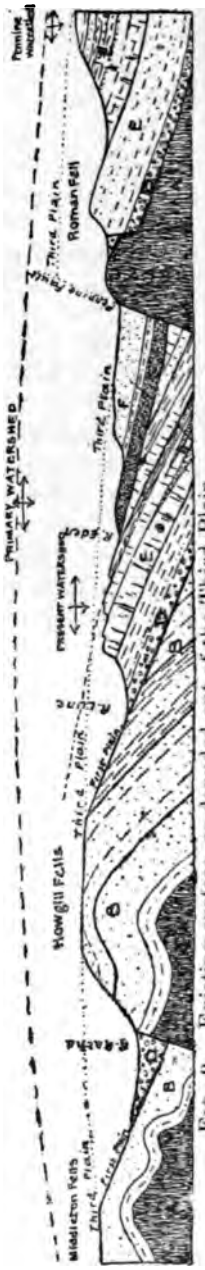


FIG. 9.—Existing surface, as denuded out of the Third Plain.

extent) from local sources.* At any rate, the Upper Old Red levelled up the hollows in the old surface, and then the land again subsided and the formation of the Carboniferous rocks commenced. The relation of these rocks to those beneath, and to the surface (or First Plain) on which they lay can best be gathered from an examination of the series of diagrams, Figs. 6, 7, 8, and 9.

It should be noted here that the First Plain now referred to extends, locally, with marvellous evenness of contour, across the edges of quite five miles of strata, in this district alone. A striking illustration of the same feature is presented by Fig. 4, which is borrowed from Woodward's 'Geology of England and Wales,' and was originally drawn partly from one of Professor Hughes's sections.

The evenness of junction seen here is generally characteristic of the First Plain. This, as will be seen presently, plays an important part in the evolution of the scenic features of the district under notice. Figs. 10 and 11, lent by the Council of the Geological Society, further illustrate the same relation.

V.—Carboniferous Rocks.

In places, there is a passage from the Upper Old Red into the Carboniferous rocks, but the advent of the Carboniferous period as a whole was marked by a considerable change of physical conditions. As the Members of the Association will have abundant opportunities of seeing for themselves, the source of the materials, and especially of the coarser materials, forming the Carboniferous rocks, was evidently different from that which supplied the materials of the older deposits beneath. At Roman Fell, for example, the lowest beds of the Carboniferous rocks are chiefly conglomerates, which consist of little else than vein-quartz, without any admixture of materials recognizable as derived from any of the known older palæozoic rocks On the other hand, the Upper Old Red, which we shall see close by, contains very little quartz, and is full of rocks like the Cheviot Porphyrites, the Silurian rocks of the Southern Uplands of Scotland, and even gneisses and other

* See J. G. Goodchild, "Geological History of Kirkby Stephen," etc., 1884, in Braithwaite's Guide.

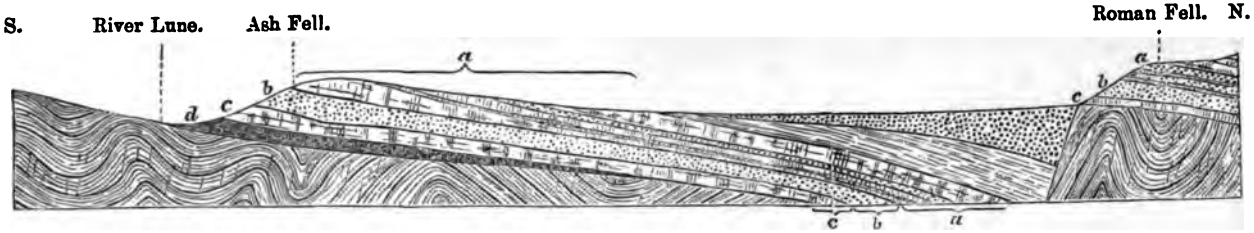


FIG. 10.—Diagram Section from the Ilowgill Fells to Roman Fell.
('Q. J. G. S.,' 1874, p. 395.)



FIG. 11.—Diagram Section along the Cross-Fell Escarpment.

foliated metamorphic rocks, which are evidently foreign to English ground.

With the advent of the Roman Fell Conglomerates terminates the enormously long period of disturbance, vulcanicity, upheaval, and denudation that prevailed after the close of the Ludlow period. Thenceforward, for some considerable time, this area again coincided with one of steady and long-continued depression, with which sedimentation nearly or quite kept pace. Deep-water and thalassic conditions prevailed at an early period in eastern Westmoreland and the parts adjoining. An old ridge extended in a general east and west direction through West Cumberland and Cross Fell. On the north side also deeper-water conditions prevailed, but as the main source of the materials forming the Carboniferous rocks lay to the north-west, thalassic conditions seem to have prevailed, on the north of the ridge, only near where the Lake District is now. (This and many other reasons, as I have repeatedly stated, point unmistakeably to the conclusion that the present Lake District does not represent a fossil island of Carboniferous age re-exposed by denudation. On the contrary, I have long maintained that the *massif* itself dates no farther back than Miocene times. Of this more presently.) More than two thousand feet of limestone was formed, almost without any partings, in the deep-water where now is South-East Westmoreland. Not so much as a fathom of it has any claim to be regarded as a coral-reef. Corals flourished there, and in great abundance, as regards both species and individuals. But of coral-reefs there are absolutely none. The quartz-conglomerates of the Roman Fell Series are on the horizon of the lower part of this great mass. The Calciferous Sandstone of Scotland and the Border is the sedimentary representative of the whole.* After the formation of the Mountain Limestone the same conditions were continued, with some breaks, and the Yoredale Rocks were formed. The typical Yoredale Rocks are found in the parts of Yorkshire adjoining the Lake District, and, in truth, the Yoredales to be seen by the Association during the 1889 Long Excursion have an equal claim to be regarded as typical. Those of the Pendle and

* J. G. Goodchild "On some Carboniferous Conglomerates in the Basin of the Eden," 'Q. J. G. S.,' xxx, p. 394.

Clithero district are of another type entirely. The Yoredale rocks exceed two thousand feet in thickness here. Above them comes the base of the Upper Carboniferous, *i.e.*, the Millstone Grit, which in Westmoreland equals in thickness the beds next below. Then came a vast, but unknown, thickness of Coal Measures. I have shown* on a former occasion that the Coal Measures once extended continuously over the whole district. Perhaps other rocks may have occurred as well; but if it was so, they have been removed without leaving any trace behind.

VI.—Post Carboniferous Rocks.

Continuous deposition, it seems, cannot go on for an indefinite length of time. Sooner or later the downward phase of the undulation is at its lowest point, and a movement begins in the opposite direction. Perhaps it would be more correct to say that each terrestrial undulation is steadily, if slowly, travelling onward in a certain direction, and that an upward movement affects, in time, any given spot, as a necessary consequence of the downward movement that preceded it. Irregularities of upheaval and subsidence, more or less disturbance of the strata, with outbursts of volcanic action, mark so many of these changes that the coincidence must be more than merely accidental. At any rate, it was long after the close of the Carboniferous period before any newer strata now in existence in the district under notice came to be laid down. The rocks had evidently been much disturbed, there had been very irregular upheaval, the beds had been again disrupted along the ancient lines of weakness presented by the Pennine Fault, and a prodigious amount of denudation had taken place, before the New Red had begun to be deposited. Judging by the facts I should say that the denuded ends of the Palæozoic rocks over a large area had been weathered into a "base level of denudation," to use Mr. Geikie's phrase. (See Fig. 7.) It was not as even, perhaps, as the First Plain, but all the rocks here were weathered down to one pretty uniform level. A good illustration of this Second Plain is given in Horizontal Section 105 of the 'Geol. Survey.'† There is no evidence what-

* 'Trans. Cumberland and Westmoreland Association,' No. 7, p. 163.

† Mr. H. B. Woodward ('Geol. Eng. and Wales,' second edition, p. 232) refers to the evenness of this surface at the base of the Neozoic rocks. The same fact has been repeatedly noticed elsewhere by others.

over that any single feature now existing had then come into being. Not the Lake District, and certainly not the Pennine Escarpment. These had undergone disturbance, but they were not left as ridges or as islands.

VII.—New Red.

An irregular upheaval followed the period of denudation referred to, or it may have been in part contemporaneous with it, as Mr. Geikie has shown was the case with the Old Red of Scotland. In this instance, as in the case of the Old Red, volcanic action seems to have been concerned in bringing about some of the peculiarities that characterized the period. Inequality of upheaval appears to have converted several large hydrographical basins into great inland lakes, into which the drainage of the areas adjoining, together with the waste of the surface around, gradually accumulated and formed the local base of the Neozoic Rocks. The prevailing directions of false-bedding in the earlier formed of these New Red sediments show unmistakeably that the rivers flowed from the east westward. (These rivers, it must be remembered, were not, in any way soever, connected with any features at present existing. It cannot be too often repeated that not a single feature of any kind now existing had come into being at this time.) There was much floating ice adrift in the old lakes on the break-up of the winter. The finer sediments dating from this period contain, in many places, large boulders, which have evidently fallen through the water of the old lake in such a manner as would have happened if melting cakes of shore-ice, charged with stones and mud, had floated out into deeper water, and dropped their burdens as they were released by the melting of the ice in the spring. Some of the beds of breccia ("Brockram"), near Appleby, must have originated in this way, though the phenomena are even better exhibited in the neighbourhood of Kirkby Stephen. Naturally, such deposits are not continuous over any large area, and we need, therefore, feel no surprise that the Brockrams seen at Appleby and in Helton Beck pass horizontally into the undivided mass of the Penrith Sandstone, as they trend in the direction of that town.* The deepest part of the old lake

* "Penrith Sandstone," 'Trans. Cumb. and West. Assoc.,' ix, p. 31; first published in the 'Carlisle Patriot,' 1881.

under notice seems to have been nearly along a line passing through Appleby and Helton. Here a mass of sandstones and breccias accumulated to a thickness of considerably over a thousand feet. Further west the thickness of the Penrith Sandstone diminishes, until it is reduced, locally, to nothing, in the northern parts of Cumberland. Curious and interesting chemical changes seem to have been in progress during the deposition of the Penrith Sandstone. The waters of the old inland lake appear to have been charged with various salts from an early period—perhaps because nearly the whole of the inland drainage was dissipated by evaporation. Sulphate of lime, carbonate of magnesia, chloride of sodium, etc., existed in unusually high proportions, and the nature of the sediments deposited was much affected in consequence. In the case of the Penrith Sandstone, for example, we have an enormous mass of quartzose sandstone without hardly a trace of mica anywhere in it—a feature almost unique of its kind. The mica and some of the other silicates appear to have undergone decomposition as fast as they were swept into the lake ; and subsequently much of the silica thus liberated was re-deposited on the grains of quartz. By this means the quartz-granules grew up into very perfect doubly-terminated hexagonal pyramids of quartz, whose perfect faces, existing in millions in every cubic foot of some parts of the stone, impart the characteristic sparkling effect so well seen in the Penrith Sandstone.

Then, again, the presence of carbonate of magnesia reacted upon the fragments of limestone and converted them, as the Association will see, into more or less pure dolomite.

Some of the limestone fragments, again, have been largely replaced by hæmatite ; and we shall see fragments in the Brockrams near Appleby, that were simply of ordinary carbonate of lime when first dropped into the lake, but now consist, through molecular replacement, of nearly pure hæmatite, just as if they were of hæmatite of older date than the New Red, instead of newer.

The sulphate of lime produced some effects whose importance is even yet not fully realized. It has long been a puzzle how it is that Red Rocks of all ages contain so few plant-remains, or none at all. We can understand why animal-remains are so few ; because no animals could well thrive in a strong mixture

of various salts; but in the case of the plants the cause of their absence is not at first so clear. It has occurred to me lately* that the real explanation is that all the vegetable organisms swept into the lake were rapidly decomposed by the excess of sulphate of lime present in the water. This view tallies well with the facts, because, in the Helton section we shall see one zone, marking a period of minimum salinity, where the sandstones are of the ordinary kind, and where the plant-remains are to be found even yet in tolerable abundance. These are the celebrated Helton Plant-Beds, one of the principal objects to be inspected during the Long Excursion of 1889. These beds have yielded to the researches of Prof. Harkness and others a fairly large assemblage of plants, of Neozoic affinities, although they are older than the Magnesian Limestones, as we shall see.

The period of minimum salinity that favoured the preservation of the plant-remains at Helton seems gradually to have again returned to former conditions. Precipitations of dolomite, in cakes all more or less lenticular and discontinuous, ensued, and the Magnesian Limestone was formed. In Helton Beck

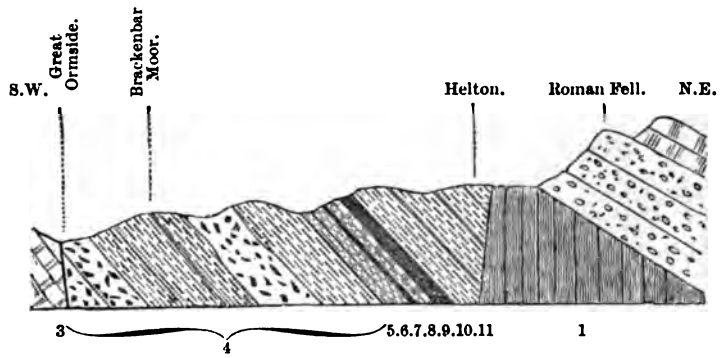


FIG. 12.—Section along Helton Beck between Great Ormside and Roman Fell, showing the succession of the New Red Rocks.

Lent by the Council of the Geological Society.

Length 5 miles. (Harkness, 'Q. J. G. S.,' 1862, p. 207.)

11. Upper sandstones (700 feet).
10. Red Shales (100 feet).
9. Magnesian Limestone (7 feet).
8. Dark-coloured sandstone (6 ft.).
7. Grey shale (3 feet).
6. Thin-bedded red sandstone (50ft.)
5. Plant-beds (20 feet).

} Fossiliferous series.

4. Penrith Sandstones and breccias (1200 feet).

2. & 3. Old Red conglomerate and Carboniferous rocks.

1. Older Palæozoic rocks.

* See 'Geol. Mag.,' July, 1889, p. 314.

this is represented by several thin bands more or less arenaceous and impure in character; but in the Bela section, only a few miles to the east, this bed is not less than thirty feet in thickness. Assuming that we are dealing with a wedge of this rock, with its base to the east, the observed rate of thickening would, if prolonged at a uniform rate, far exceed any thickness recorded in Durham, at the distance of that city from Helton. So there is no reason why the Magnesian Limestone should not have been continuous from the one place to the other; continuous, that is, as far as could be expected of such a chemical precipitate. (Fig. 12).

Before passing to the higher beds, it is important to observe that animal life in the Lower New Red, which is locally represented in such profusion elsewhere, is here entirely absent. There is not so much as a single shell, or a bone, to be found anywhere in these beds. The Penrith Sandstone (=Rothe liegende) does, it is true, yield traces of life. But these vestiges are confined to fossil impressions of the footmarks of the strange, uncouth, animals that wandered on the shores, or waded in the shallows, of the old lakes. Mr. G. Varty Smith's researches* have brought to light many different forms of these animals. They seem to have been, in form, something like Iguanodons, as they threw the main weight of their bodies upon their larger hind limbs and their tail, and only used their fore-limbs in much the same manner as a kangaroo does. The Jardine Collection of these footprints, from Dumfries, now in the Edinburgh Museum of Science and Art, shows an extraordinary variety of these ichnites, which would seem to entitle the Lower New Red to the designation of the Age of Reptiles almost as much as the Jurassic rocks. Whether these animals belonged to the Sauropsida or to the Ichthyopsida the evidence at present existing will not enable us to judge.

After the deposition of the Magnesian Limestone occurred a somewhat abrupt change of conditions, and again a high degree of salinity. It was then that the Lower Gypseous Marls (the base of the Bunter as many think) were formed. These marls graduate upwards into the St. Bees' Sandstone, which will be examined in several localities under the President's guidance. At Helton Beck these yield desiccation-marks, ichnites similar

* 'Q. J. G. S.,' xl, 479.

to those in the Penrith Sandstone, casts of bay-salt, rain-spots, and other evidence of shallow-water conditions. These sandstones accumulated to a thickness of quite two thousand feet. In many parts they are much mottled, poikilitic, bigarré, or Bunter; and they locally become more or less pebbly.

What happened after the deposition of the St. Bees' Sandstone is a question much in dispute. Mr. Holmes has much to say upon that head. (*Vide supra*, p. 246.)

At any rate, whatever beds were deposited next above have been denuded from the greater part of the district specially under notice. I have no doubt, in my own mind, that all the rocks up to the Lias, and even all the Jurassic rocks, once overspread the whole district, and were continuous with those of other parts of the kingdom. The Pennine Fault and the disturbances that accompanied that disruption, have facilitated the removal of those rocks over certain areas, while they have, on the other hand, helped to preserve them elsewhere.

VIII.—Post Jurassic Events.

From Lower Jurassic times onward we lose sight of the history of Edenside until Miocene (or Oligocene) times. Then, as we know, great disturbances affected these parts, and the Armathwaite (Cleveland) Dyke was intruded. But although direct evidence is wanting, many considerations have led me to believe (and to state in print again and again) that after Jurassic times this area, and much around it, underwent extensive denudation, which resulted in the formation of what I term the Third Plain (See Fig. 8). Then the land subsided and the Cretaceous rocks were spread out far and wide over what are now hill and valley. In those times, as the diagrams will show, none of the features now existing had been developed. I believe that nearly all our mountain plateaux belong to this Third or Subcretaceous Plain, and many other broad surface features also.

IX.—First Appearance of the Mountains.

Then, long subsequently, and possibly in Middle Eocene times, the whole area underwent its last and most important upheaval. The land then assumed for the first time the character of a permanent terrestrial surface, and the courses of the rivers of the district were also, for the first time, marked out. A reference to Fig. 9 will serve to make this clearer. It will be seen by this that

the rivers did not flow then quite as they flow now. The main water-shed of northern England lay then, not where it is now, but above the lowlands of Edenside. The inosculating valleys, and many other anomalies in the courses of the rivers, are quite inexplicable on any other theory than that all the principal rivers of northern England took their rise somewhere above where Appleby is now. This subject is discussed in some detail in my paper on the River Eden, published in 1880, and now reprinted in No, xiv of the 'Trans. Cumberland and Westmoreland Association.' Another aspect of the same question is discussed in my 'Physical History of Greystoke Park and the River Petteril,' in No. xiii of the same journal.

Out of the three plains so often alluded to—after they had been more or less folded, tilted, faulted, and eventually re-exposed by denudation—subaërial forces, acting through an immense period of time, have shaped all the features of first magnitude: the great plateaux, the larger lowland plain, and the escarpment. The features of secondary magnitude, as one may term them, are mainly due to variations in the ratio of horizontal to vertical waste presented by their respective rock-masses. These features, however, have been more or less modified by glacial action, which I shall now proceed briefly to describe.

X.—The Glacial Period.

Long after all the valleys had been shaped out, and the orography of Edenside had assumed nearly its present form, decreased summer temperature gave rise to local glaciers. For a very long period these seem to have gone on increasing in proportions; but, at the same time, they appear in every case to have flowed in the same direction as the existing drainage. The principal result appears to have been the removal of nearly the whole of the rock that had been loosened by pre-glacial weathering and its transference to a lower level. This was chiefly effected along the bottoms and the sides of the valleys, which thereby were gradually both deepened and widened. Later on, still colder conditions supervened; the local glaciers became confluent; their upper surface rose to higher levels; and they advanced farther and farther across the area lying outside the mountains. There is reason to believe that this state of things continued for a long time; and that, for a

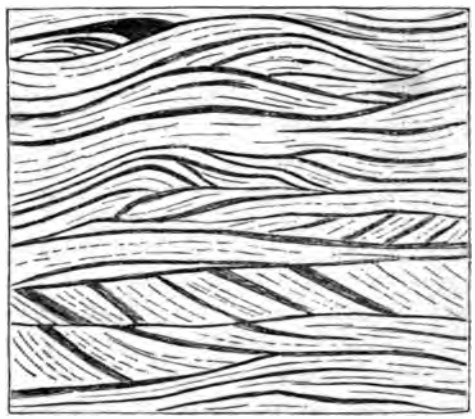


FIG. 13.

Laminated Clays and Loams more or less affected by thrust planes due to the movements of the melting ice above it. Length about 12 inches. Cutting in the Midland Railway, near Langanby.



FIG. 14.

Section across the Midland Railway near Langanby, showing alternations of Till (T.), Sand and Gravel (S. G.), and Laminated Clays (C.) overlying New Red Marl (in the right hand corner).

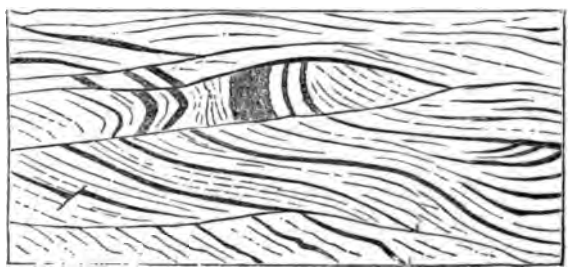


FIG. 15.

Disturbed Laminated Clays, probably originally deposited in nearly horizontal sheets, and afterwards deranged by lateral movements resulting from the down-settling of the melting ice-sheet above. Length of section, 9 inches. Midland Railway Cutting near Langanby.

period of great length, the whole of Edenside was occupied by one vast glacier, which, for the greater part of the time, flowed chiefly in the same directions as the drainage does at present. There seems reason to believe also that enormous accumulations of moranic material gathered in this way on the lowlands around Carlisle and in the Solway. It was here, I believe, that the chief accumulations of Shap Granite, and of the many other upland rocks that went with it in the drift, were first deposited, and it was during this period that the wonderful scoring, grooving, and glacial erosion generally, that characterizes Edenside, were accomplished. All the old lakes of Edenside—Appleby Mere, Langanby Mere, the great lake at Threlkeld, as well as the lakes now existing as such, were eroded chiefly at this period.*

By-and-bye, as the summer temperature continued to fall, and less and less of the winter's snow melted, the whole of the sea to the north-west of the British Isles became completely filled with ice. Under these conditions the northern glaciers were no longer able to flow seawards. The sea-ice pressed back the outer ends of the glaciers from the land, the ice-rivers were dammed at their mouths, and the only course open to the icy flood lay to the south. So there was set up a southward flow of the higher parts of the ice, south-easterly on the southern coast of Scotland, and south-westerly along the eastern shores of England. There was no longer an outlet for the Edenside ice by way of the Solway, for the icy flood advancing from Galloway stopped all egress in that direction. So, after a time, the ice around Carlisle began to flow in the lines of least resistance open to it. One of these lay eastward over the Bewcastle Fells, and thence down the valley of the Tyne to the east coast. The other direction of least resistance lay up the Eden Valley itself. So we find the glacial tide turned inland along these two directions at the time referred to. Vast quantities of *débris* were swept along in the ice in directions diametrically opposite to what they had taken at an earlier stage. Eventually the icy flood, closely pressed in many directions by local currents, flowed past Appleby, over the east of Roman Fell, and thence over the uplands of Stainmoor out to the Plain of York, where it

* See the lines showing the 400 feet and the 500 feet contours on the map, Fig. 16; and see also "Trans. Cumb. and West. Assoc.,' xiii, p. 105.

was joined by the current that had travelled round by the Tyne Valley and the eastern parts of Durham.*

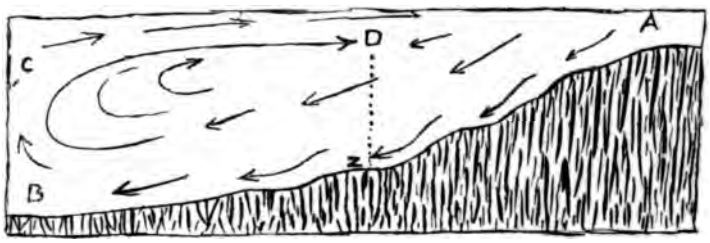


FIG. 16.

Diagram to illustrate the transportation of boulders in directions contrary to the flow of the sole of the Ice-Sheet. Ice carrying boulders down hill and outwards from the centres of dispersal in a direction from A to B, is met at B by ice-currents setting in contrary direction (in most force at higher levels). At B the opposing forces are balanced, and the direction of least resistance is then mainly upward. Arrived at higher levels, the local current becomes more and more affected by the influence of the currents setting inland, and the ice then moves with its freight of mixed local and extraneous detritus in the direction of C, D. On the melting of the ice, the sediment dispersed throughout it, is deposited on the rock surface below; the boulders, both of local and extraneous origin, between D and Z, for example, being deposited at Z. [It should be observed that in hardly any case did the direction of movement of the outflowing current lie diametrically opposite to that of the current opposing it. The curve of transportation was probably hardly ever entirely in the same plane.]

It was at this same period that the North Sea was blocked by ice, and the mouths of our south-country rivers were dammed. The brick-earths of the Thames-Valley system are simply the flood-deposits contemporaneous with the glacial phenomena of Stainmoor.†

The icy flood left its impress upon the surface in a variety of forms. I am still of opinion that the great caldron-shaped "coums" or cirques of Edenside and around were formed by the ice at this period. Interrupted ice-groovings on a large scale, a hundred feet in depth, and as many fathoms in width,

* Reference should be made to the glacial phenomena registered on the small map appended to this paper. See also "Ice Work in Edenside" ('Trans. Cumberland and Westmoreland Association,' No. xi, p. 111, *et seq.*). 'Q. J. G. S.,' xxxi, and 'Geol. Mag.,' 1875, p. 360.

† "Notes on some Superficial Deposits of North Kent," 'Proc. Geol. Assoc.,' ix, p. 151.

traverse Edenside from end to end. Big troughs were scooped out along the hill-sides; ice-smoothed surfaces are nearly everywhere of common occurrence. Some of these will be seen: others are shown upon the map, Fig. 17.

It is a remarkable fact that, immediately after the climax of the Glacial period, a somewhat abrupt amelioration of the climate ensued. Certain it is that after the ice had moved inland and uphill, as I have described, it did not gradually break up into small glaciers and pass in reverse order through the series of changes whereby it attained its maximum. On the contrary, it seems to have quietly melted away on the spot without perceptible movement of any kind.

The stony and earthy matter transported in, on, and under the ice gave rise, as the ice melted, to those varied forms of glacial sediment that we call till, glacial sand and gravel, eskers, etc. (See Figs. 13, 14, 15, and 16).

Some time after the ice had left its stony and muddy sediment behind, a second and much less severe period of cold set in; and small local glaciers occupied a few of our mountain valleys. These minor glaciers, however, accomplished little else than the transfer of some of the older Glacial Drift to lower positions outside. Some of these later moraines will be seen by the Association at Cosca, near Dufton, and elsewhere.

Since the Glacial period subaërial denudation has accomplished results so trifling, in Edenside, at all events, that one may hesitate to believe that the close of that period can be distant from our own time more than a few thousand years at the very most.

APPENDIX.

For a list of works relating to the Geology of Cumberland and Westmoreland reference should be made to Mr. Whitaker's Bibliography, published in the 'Trans. Cumberland and Westmoreland Association,' No. vii, p. 13.

Since that list was printed, several publications of more or less importance have appeared. Among these may be mentioned the following:—A second edition of the Geol. Survey 'Memoir on the Geology of the Country around Kendal, Sedbergh, and Seba,' which has been edited, and, in part, re-written, by A. Strahan,



M.A., F.G.S. Messrs. Aveline and Hughes' account of the Silurian rocks of the Lake District, in the 'Memoir,' should certainly be read by those intending to take part in the Excursion. For a concise account of the Ordovician rocks as a whole, read Mr. Ward's "Physical History of the Lake District," 'Geol. Mag.' Dec. ii, Vol. vi, No. 2, p. 49, and No. 3, p. 110. A valuable summary of the facts has already appeared in Mr. Hudleston's "Geology of the Neighbourhood of Keswick," 'Proc. Geol. Assoc.' vii, p. 213. Woodward's 'Geology of England and Wales,' 2nd ed. (1887), should also be consulted, as it contains full details of all the geological features of importance. An outline of the geological history of Westmoreland (by J. G. G.) is given in Braithwaite's "Guide to Kirkby Stephen and Appleby," Kirkby Stephen, 1884. The article—"Westmoreland," 'Encyclop. Brit.' new ed. Vol. xxiv (by J. G. G.), contains an account of the chief features of geological interest in the county. Mr. Teall's papers in the 'Quart. Journ. Geol. Soc.' should be read, especially the one in the 'Quart. Journ. Geol. Soc.' for May, 1884, dealing with the Armathwaite Dyke. Lastly, Messrs. Marr and Nicholson's valuable paper on the "Stockdale Series," 'Quart. Journ. Geol. Soc.,' No. 176, Nov., 1888, p. 654, deals with one of the most interesting features in the geology of the north-west of England, the history and the palæontology of the Graptolitic Mudstones.

Mr. Holmes's papers on the neighbourhood of Carlisle will be, of course, in the hands of all the members of the party. The list includes, amongst others, "The Permian, Triassic, and Liassic Rocks of the Carlisle Basin," 'Quart. Journ. Geol. Soc.,' Vol. xxxvii, p. 286; "Notes on the Geology of Cumberland North of the Lake District," 'Proc. Geol. Assoc.,' Vol. vii, p. 404; "Raised Beach between Whitehaven and Bowness," 'Trans. Cumb. and West. Assoc.,' No. ii, p. 68; "Submerged Forest off Cardurnock, on the Solway;" and "The Destruction of Skinburness by the Sea about the year 1305," *ibid.*, No. vi, p. 121; "Physical Geography of North-West Cumberland,' *ibid.*, No. vi, p. 167;* "On the Distinctive Colours of the Carboniferous and Permian or Triassic (Poikilitic) Rocks of North Cumberland," *ibid.*, No. vii, p. 79; "Water Supply in the Carlisle Basin," *ibid.*, No. viii, p. 17; "Coal Measures below the New Red Sandstone," *ibid.*, No. viii, p. 208; "Discovery of Mammalian Remains at Silloth," *ibid.*, No. viii, p. 209; "*Bos primigenius* and the Chillingham Wild Cattle,"

ibid., No. viii, p. 211 ; "Note on Shawk Beck," *ibid.*, No. viii, p. 211 ; "Note on the best Locality for Coal beneath the Permian Rocks of North-West Cumberland," *ibid.*, No. ix, p. 109 ; "The Carlisle Water Supply," *ibid.*, No. ix, p. 213 ; "Section North of Silloth," *ibid.*, No. ix, p. 213 ; "Silloth New Dock," *ibid.*, No. ix, p. 214 ; "Changes of Channel in the Solway," *ibid.*, No. ix, p. 215 ; "Ancient Lake Dwellings in Galloway," *ibid.*, No. ix, p. 215 ; "The Probable Existence of Lake Dwellings in Cumberland," *ibid.*, No. ix, p. 217 ; "Notes on the Purple-Grey Carboniferous Rocks and the Whitehaven Sandstone," *ibid.*, No. xi, p. 146.

References to some of the papers by Mr. Goodchild are given under their respective subjects as footnotes to the paper on the "Geological History of Edenside."

J. G. G.

* The 'Trans. Cumb. and West. Assoc.' can be obtained of the Messrs. Coward, 75, Scotch Street, Carlisle.

A Synopsis of the Fossil Fishes of the English Lower Oolites.

By A. Smith Woodward, F.G.S., F.Z.S., of the British Museum (Natural History).

(Read January 3rd, 1890.)

The Lower Jurassic Fish-fauna is well known, principally from the discoveries in various horizons of the English Lias, and the fishes of the Upper Jurassic are still more satisfactorily revealed by the remarkable state of preservation in which they occur in the Lithographic Stones of Bavaria, Würtemberg, and France. In the Jurassic rocks of intermediate date, however, fish-remains are either very rare or fragmentary, and thus do not afford much definite information as to the species—or even genera—represented. Scales, teeth, and isolated bones of the head and pectoral arch are almost the only ichthyolites met with in some of these formations; but as such fossils are frequently discovered by collectors, and occasionally prove of sufficient value to be discussed in connection with palæontological or stratigraphical questions, it seems advisable to attempt, at least, their provisional determination. Names may well be adopted for the more striking specimens that exhibit constant characters, and, even if these names have no precise biological significance, they will probably be of use to those contrasting the faunæ of the various horizons.

More than forty years ago Agassiz, in his 'Recherches sur les Poissons Fossiles,' undertook a comparative study of fish-fragments, of the character mentioned, from the English Stonesfield Slate, publishing a number of names, of which very few were defined; and the only subsequent contribution to our knowledge of the subject is the series of outline sketches of typical specimens given in Professor Phillips' 'Geology of Oxford.' The accumulated discoveries of many years now in the British Museum, the Museums of Oxford and Cambridge, and the collection of Mr. Thomas Jesson, F.G.S., have induced the present writer to attempt a revision and extension of the results of previous researches; and it is hoped that a brief statement of the facts already known concerning the fish-faunæ, not only of the Stonesfield Slate, but also of other English Lower Oolites, may lead to the recognition of further specimens that have not yet been studied in the light of

modern discoveries. It is proposed to offer a series of illustrated descriptions of the more recognizable fish-fragments, with especial reference to those bearing the undefined names proposed by Agassiz. The majority of the specimens described are preserved in the British Museum, but thanks are also due to Prof. T. McKenny Hughes, F.R.S., and Prof. A. H. Green, F.R.S., for the loan of material from the Museums of Cambridge and Oxford; and the writer is especially indebted to Mr. Thomas Jesson, F.G.S., for the opportunity of investigating his unique collection from the Great Oolite of the neighbourhood of Northampton. The diagram woodcuts, from Professor Phillips' 'Geology of Oxford,' are reproduced by the courtesy of the Delegates of the Clarendon Press.

Full references to the literature of each genus and species will be found in Woodward and Sherborn's recently published 'Catalogue of British Fossil Vertebrata,' and it has thus not been deemed necessary to repeat them here.

SELACHII.

Genus *Hybodus*, Agassiz.

Teeth and portions of spines of sharks are among the commoner vertebrate fossils of the English Lower Oolites, and seem to be referable to at least four genera (*Hybodus*, *Acrodus*, *Asteracanthus*, and *Nemacanthus*).* The well-known fluted dorsal fin-spines, with posterior denticles, characteristic of the genera *Hybodus* and *Acrodus* (Fig. II, Nos. 1, 2, 6), have been recorded from the

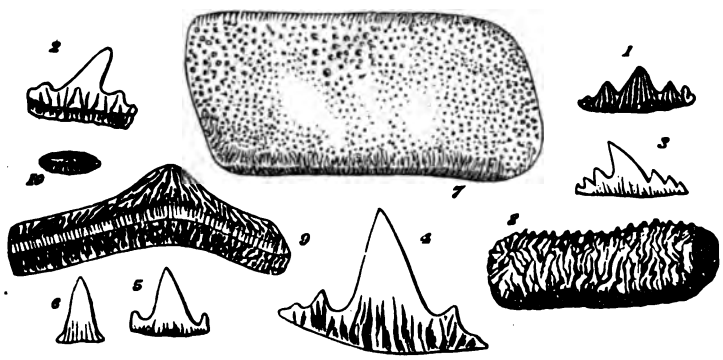


FIG. I.—Selachian Teeth from the Stonesfield Slate.—1-3, *Hybodus polyprion*, Ag. 4-6, *Hybodus grossiconus*, Ag. 7, *Strophodus magnus*, Ag. 8, *Strophodus lingualis*, Phil. (enlarged). 9, *Strophodus tenuis*, Ag. 10, *Acrodus leiodus*, A. S. Woodw. [From Phillips' 'Geology of Oxford.']

* Full details and references are given in the Catalogue of Fossil Fishes *in the* British Museum, Part i (1889).

Inferior Oolite of Lincolnshire, the Stonesfield Slate, and the Great Oolite of Northamptonshire and Buckinghamshire. The cuspidate teeth are also everywhere represented, and, while the spines are incapable of being precisely assorted into "species," the teeth seem to justify the recognition of three forms, which have received the names of *Hybodus polyprion*, *H. grossiconus* (Fig. I, Nos. 4-6), and *H. levis*. All these fossils have high crowns, with well-developed lateral denticles; those of *H. polyprion* (Fig. I, Nos. 1-3) sometimes exhibit a remarkable resemblance to the teeth of the earlier species of *Notidanus;* and those of *H. levis* have a stout, depressed base, as large as that of the so-called *Hybodus minor* (Rhætic) and *Synechodus* (Cretaceous).

Genus *Acrodus*, Agassiz.

A few ovate crushing teeth, with a gently rounded crown, marked by striations radiating from a central line, prove the occur-

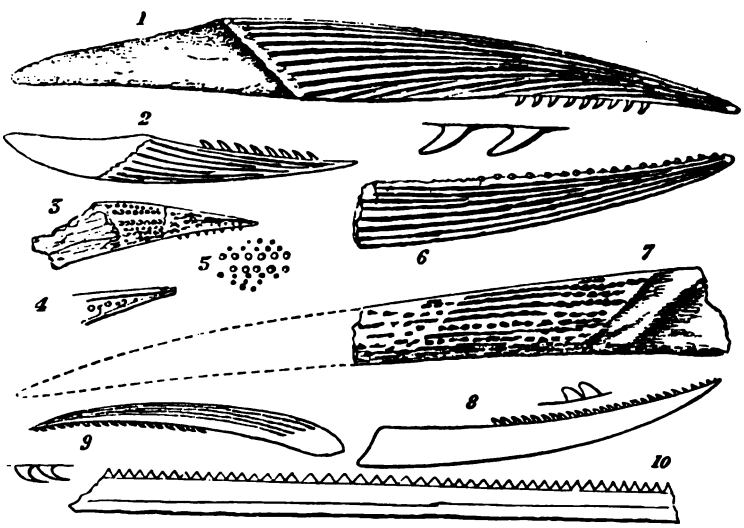


Fig. II.—Selachian and Chimæroid Spines from the Stonesfield Slate.—1, *Hybodus dorsalis*, Ag., with two denticles separately enlarged below. 2, *Hybodus apicalis*, Ag. 3-5, *Nemacanthus brevis*, Phil., with apex (4) and ornament (5) enlarged. 6, *Hybodus marginalis*, Ag. 7, *Asteracanthus semisulcatus*, Ag. 8, *Leptacanthus serratus*, Ag., with two denticles separately enlarged above. 9, *Leptacanthus semistriatus*, Ag., with two denticles separately enlarged below. 10, *Pristacanthus securis*, Ag. [From Phillips' 'Geology of Oxford.']

rence of typical species of *Acrodus* in the Stonesfield Slate, in the Great Oolite of Gloucestershire, and in the Forest Marble of Wiltshire. Very small depressed teeth, with relatively coarse, superficial wrinkles, occur in all these formations, constituting the sole evidence of the species, *A. leiodus* (Fig. I, No. 10); and two examples of a high-crowned tooth, characterized by a pair of lateral bosses and numerous sharp, branching wrinkles upon the coronal surface, indicate the occurrence of a second form, *A. leiopleurus*, in the Great Oolite of Minchinhampton, and in an unknown horizon.

Genus *Asteracanthus* (*Strophodus*), Agassiz.

Discoveries by Mr. Alfred N. Leeds, in the Oxford Clay of Peterborough, have proved that the teeth named *Strophodus* pertain to the shark, whose dorsal fin-spines were, at an earlier date, termed *Asteracanthus*. At present, however, it is impossible to correlate the spines and teeth in any species except *Asteracanthus ornatissimus*, and those of the Lower Oolites must still retain their provisional names. The broad, flat, quadrate teeth, and the gently tumid anterior teeth of *Strophodus magnus* (Fig. I, No. 7), are known almost everywhere;* while a narrower form, with a more or less strongly arched crown, has an equally wide distribution, and is appropriately named *S. tenuis* (Fig. I, No. 9). When unabraded,



FIG. III.—Jaw of *Asteracanthus* (*Strophodus medicus*, Owen). Great Oolite, Caen, Normandy. This is the only known specimen showing the arrangement of the teeth.

* Early figures of these teeth are given by C. Prevost, 'Ann. Sci. Nat.,' Vol. iv (1825), Pl. xviii, Figs. 11-14.

these teeth are superficially marked with a fine rugosity; but a third species (*S. lingualis*), of smaller size, first recognized by Professor Phillips, exhibits very narrow teeth, marked with relatively coarse reticulations, of which the transverse lines are especially prominent (Fig. I, No. 8). The latter form is known from the Stonesfield Slate and the Forest Marble of Malmesbury, Wiltshire. Only two "species" of spines are recognized: *Asteracanthus semisulcatus*, frequently exhibiting its ornamental tubercles fused into more or less continuous ridges (Fig. II, No. 7); and *A. acutus*, recorded from the same formation, the Great Oolite of Enslow Bridge, and the Cornbrash of Botolph's Bridge, Peterborough.

Genus *Nemacanthus*, Agassiz.

As already recognized by Agassiz and Phillips, a small Selachian spine from the Stonesfield Slate is referable to *Nemacanthus*—a genus of which the type species occurs in the Rhætic Beds. The spine (Pl. III, Fig. 1, and Fig. II, Nos. 3-5) is short, acutely pointed distally, and broad at the base. Its anterior margin bears a shining keel of gano-dentine. The posterior face is evidently flattened and narrow, with a mesial groove and a series of minute denticles on each edge; and the sides are ornamented with several regular, longitudinal series of large tubercles. This ichthyodorulite differs from the other known species in its relatively short and broad proportions—a circumstance rendering Phillips' name of *N. brevis* appropriate.

Nemacanthus brevis, at first sight, appears too small to pertain to either of the sharks represented in the Stonesfield Slate by the teeth named *Hybodus*, although some facts suggest a possibility that the spine may be correlated with the so-called *Hybodus levis*. It has already been remarked* that the typical *Nemacanthus monilifer*, of the Rhætic, is probably the spine of "*Hybodus minor*," and the *Hybodus levis* of Stonesfield makes some approach to the last-mentioned form of dentition in the stout, depressed root, characteristic of all the teeth.

Selachian Vertebræ.

Selachian vertebræ occur in most of the Lower Oolites, and as these, in transverse section, exhibit radiating plates (*i.e.*, are

* Smith Woodward, "On some Remains of Fossil Fishes from the Rhætic Beds of the Spinney Hills," 'Trans. Leicester Lit. and Phil. Soc.,' n.s., Pt. xi (1889), p. 18.

"asterospondylic"), they evidently pertain to one of the genera mentioned above.

CHIMÆROIDEI.

Genus *Ischyodus*, Agassiz.

Beak-shaped and triangular pieces of soft bone, with more or less extensive patches of punctate or lamellated tooth-substance, are sometimes met with in the Lower Oolites, and may be ascribed to Chimæroid Fishes. The beak-shaped mandibular dental plates are all of one general type, thin and laterally compressed; but the posterior upper plates (termed palatine or maxillary) indicate the occurrence of two distinct genera—*Ischyodus* and *Ganodus*. Each of the palatine dental plates of *Ischyodus* (Pl. III, Fig. 3) has two patches of tooth-substance on the inner side of the grinding surface, one on the outer side, and one intermediate area posteriorly; the hinder border is also characteristic, being only very slightly notched. The species represented are difficult of determination, but *Ischyodus Colei* and *I. emarginatus* are evidently two forms.

Genus *Ganodus*, Egerton.

The palatine plate of *Ganodus* (Pl. III, Fig. 4) is deeply notched behind, the excavation being continued forwards as a median longitudinal groove, gradually becoming shallower, and separating a narrow band of inner dentine-patches from a much smaller outer series of a similar character. Many forms of mandibular teeth theoretically ascribed to the same genus have received specific names, and an attempt will be made to revise the list in the forthcoming Brit. Mus. Catal. Foss. Fishes, Part II.

Two "species" of dorsal fin-spines of Chimæroid fishes from the Stonesfield Slate, now in the British Museum, were named *Leptacanthus semistriatus* and *L. serratus* by Agassiz, and, from their small size, these may probably be referred to *Ganodus*. They are slender, laterally compressed spines, gently arched, finely striated, and with a double series of large posterior denticles (Fig. II, Nos. 8, 9).

ICHTHYODORULITE.

Genus *Pristacanthus*, Agassiz.

Only one example of the remarkable spine, *Pristacanthus securis*, was recorded by Agassiz from the English Lower Oolites; and, so far as the present writer is aware, this specimen is still unique. It

is a portion of the lower extremity of a large spine imbedded in the characteristic matrix of the Stonesfield Slate, preserved in the Museum of the Royal College of Surgeons, and, by kind permission of Professor Stewart, shown of the natural size in Pl. III, Fig. 2. Spines of this form from the Great Oolite of Caen, Normandy, attain to a great length, and, as remarked by Agassiz, they seem to be identical with the Stonesfield species. They are hollow, and exhibit extreme lateral compression, with a sharp edge in front and behind, the latter bearing a single, regular, close series of triangular, laterally-compressed denticles. A smooth longitudinal band of enamel (gano-dentine) covers the anterior half of each flattened side, and there are no tubercles or ridges. Nothing is known of the relationships of these singular weapons; they evidently belong to cartilaginous fishes, and, as Agassiz originally pointed out, they are most suggestive of the dorsal fin-spines of the Chimæroids.

DIPNOI.

Genus *Ceratodus*, Agassiz.

A tooth of the Dipnoan fish, *Ceratodus*, from the Stonesfield Slate, was described and figured by Agassiz under the name of *C. Phillipsii*; and this still remains as the sole undoubted record of the occurrence of the genus in the Jurassic rocks of Europe.

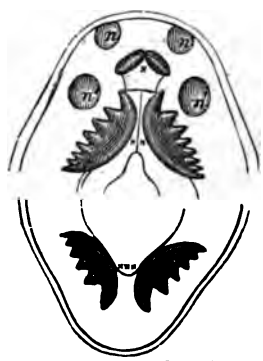


FIG. IV.—Mouth of the recent *Ceratodus Forsteri*, from Queensland.—*x*, Vomerine teeth. *xx*, Palatine teeth. *xxx*, Mandibular teeth. *n*, Nasal openings.

The specimen was originally in Professor Phillips' collection, and seems to have been lost; and the only other fossil tooth hitherto ascribed to the same species* differs so much from the figure and

* L. C. Miall, 'Sirenoid and Crossopterygian Ganoids,' Pt. I (Palæont. Soc., 1878), p. 32, Pl. v, Fig. 13.

description given by Agassiz, that its identification is very doubtful, while the formation and locality from which it was derived are not definitely known. It is thus of much interest to find in Mr. Jesson's collection the greater portion of an abraded tooth agreeing precisely with the original diagnosis of *C. Phillipsii*, and only differing from the type in being one-third larger. This fossil (Pl. III, Figs. 5, 5*a*) exhibits the three anterior "horns," is entirely disengaged from matrix, and was obtained from the Great Oolite near Northampton. The tooth is comparatively thin, and the "horns" are angulated and separated by feeble grooves, continued far towards the angle of the inner border. No scales or bones of the same genus have as yet been detected, and the tooth now described being the sole example observed by the present writer, indicates the rarity of its occurrence.

GANOIDEI.

Undetermined Cœlacanth Genus (? *Undina*, Münster).

A jugular plate of a Cœlacanth ganoid, from the Stonesfield Slate, was figured by Prevost,* and there are examples both of this bone and of the pterygo-quadrate (Pl. III, Fig. 6), from the same formation, in the British Museum and in the Oxford Museum. The fossils, however, do not suffice for generic determination.

Genus *Lepidotus*, Agassiz.

Detached scales of the well-known ganoid *Lepidotus* are common in the Lower Oolites; the teeth are sometimes met with; and a tail, showing portions of the median fins, from the Great Oolite of Collington, is preserved in the British Museum (No. 47137). Though at present incapable of precise definition, these remains are provisionally grouped together under the name of *Lepidotus unguiculatus*, which was first given by Agassiz to a portion of a fish from Daiting, Bavaria. A single scale from Stonesfield, now in the British Museum, was noticed by Agassiz, and another, from the Great Oolite of Northampton, is shown in Pl. III, Fig. 8. All the principal scales are characterized by the presence of two, three, or more denticulations in the lower half of the hinder margin, and hence the specific name. A portion of mandibular dentition, from the Great Oolite of Enslow Bridge, is shown from above in Pl. III, Fig. 7, and from two lateral aspects in

* 'Ann. Sci. Nat.,' Vol. iv (1825), Pl. xviii, Fig. 20.

Figs. 7*a*, *b*; the marginal teeth (*mar.*) are more slender than the others, and in Fig. 7*a* a successional tooth (*s.*) is seen, partly upturned. The imperfect mandible from Stonesfield, named *Pycnodus rudis* by Phillips (Fig. V, Nos. 1, 2), also seems to be referable to *Lepidotus*.

An imperfect isolated bone from the Stonesfield Slate, in the Oxford Museum, is probably to be regarded as the suboperculum of *Lepidotus*, and this was named *L. tuberculatus* by Agassiz in reference to its conspicuous ornamentation.

Genus *Pholidophorus*, Agassiz.

The genus *Pholidophorus* doubtless occurs in the Lower Oolites, but no undoubted specimens have hitherto been recognized. The roof of a skull from the Stonesfield Slate, now in the British Museum, is the type specimen of *Pholidophorus minor*, Agassiz; but it may with equal probability be referred to *Leptolepis*. The various fragments ascribed to the same species by Phillips are regarded by the present writer as pertaining to *Aspidorhynchus*, *Belonostomus*, and *Macrosemius*; and the so-called *Pholidophorus Flesheri*, Agassiz, from the Great Oolite of Blisworth, is rightly ascribed by v. Zittel to *Ophiopsis*.

Genus *Ophiopsis*, Agassiz.

This genus is distinguished from *Pholidophorus* by the considerable elongation of the dorsal fin, the slenderness of the trunk, and the pointed form of the snout. As observed by v. Zittel,* the nearly complete type specimen of "*Pholidophorus Flesheri*," Agassiz, from the Great Oolite of Blisworth, exhibits such characters, and must thus be removed to *Ophiopsis*.

Genus *Macrosemius*, Agassiz.

The name of *Macrosemius brevirostris* was given by Agassiz to a portion of jaw from the Stonesfield Slate, now in the British Museum, and shown in Pl. III, Fig. 9. The specimen is probably a maxilla, and exhibits a deep expansion behind, though narrow in front. A regular series of about twelve long, styliform teeth, each somewhat tumid at its middle, and with the apex slightly incurved, occupies about two-thirds of the oral margin of the bone.

* K. A. von Zittel, 'Handbuch der Palæontologie,' Vol. iii (1887), p. 217.

The premaxillæ and maxilla, doubtfully ascribed by Phillips to *Pholidophorus minor* (Fig. V, Nos. 8, 9), most probably pertain

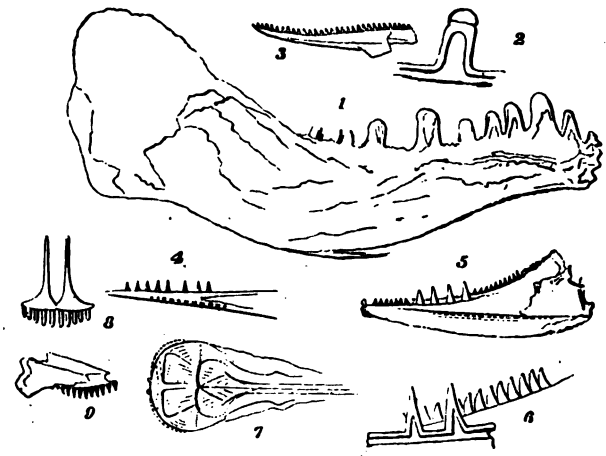


FIG. V.—Remains of Ganoid Fishes from the Stonesfield Slate.—1-2, Mandibular ramus of *Lepidotus unguiculatus*, Ag., with tooth enlarged. 3, Maxilla of *Aspidorhynchus crassus*, A. S. Woodw. 4, Mandibular symphysis of *Belonostomus leptosteus*, Ag. 5-6, Mandibular ramus of *Aspidorhynchus crassus*, A. S. Woodw., with teeth enlarged. 7, Roof of cranium of *Belonostomus leptosteus*, Ag. 8-9, Premaxillæ and (?) maxilla of *Macrorosemius brevirostris*, Ag. [From Phillips' 'Geology of Oxford.']

to the same fish, and, though the generic determination must still be regarded as provisional, both the jaws and dentition seem to be most nearly paralleled by those of the typical *Macrosemius* of the Upper Jurassic Lithographic Stone.

(?) Genus *Caturus*, Agassiz.

Some mandibular rami from the Stonesfield Slate, now in the British Museum, are labelled *Caturus pleiodus* by Agassiz, but it seems impossible at present to determine the genus satisfactorily. One of these specimens is shown, from the outer aspect, in Pl. III, Fig. 10. The bone is stout, but not deep; a series of blunt conical teeth, irregular in size, extends along the greater part of the dentary element, and a few large nutritive foramina are observed outside below the tooth-bearing margin. In many respects the fossil is suggestive of a reptilian jaw.

Genus *Leptolepis*, Agassiz.

Several typical fragments of *Leptolepis* occur in the Stonesfield Slate. The preoperculum is shown in Pl. III, Fig 17, and may be at once recognized by the prominent radiating flutings, which are confined to the lower expanded "limb" of the bone; the ascending limb is narrow, and meets the lower part in a sharp angulation. An operculum and maxilla are represented in Pl. III, Figs. 16, 18, and an unmistakable dentary bone of the lower jaw in Pl. III, Fig. 19. The latter is easily recognized by the long, broad, upwardly-directed process near its anterior end. The proportions of this element and the characters of the preoperculum, taken together, justify the adoption of the provisional name of *Leptolepis disjectus* for the Stonesfield species.

Genus *Aspidorhynchus*, Agassiz.

The occurrence of the long-snouted ganoid, *Aspidorhynchus*, in the Stonesfield Slate, has already been recorded,* and two examples of the skull, with one of the mandible, are shown in Pl. III, Figs. 11, 12. As seen in side-view (Fig. 11), the skull is not much elevated, sloping very gradually forwards into the well-developed rostrum; and the latter is rounded, exhibiting no sutural lines, but superficially marked with a coarse rugosity. The orbit (*orb.*) and nasal opening (*na.*) are observed in their usual situation; and one of the large teeth at the base of the rostrum is especially prominent. The roof of the skull (Fig. 12) is long and narrow, with almost parallel sides behind; the parietal bones (*pa.*) occupy a relatively small space posteriorly; the frontals (*fr.*), separated by a wavy median suture, are seen immediately in front; and all the bones are externally ornamented by fine vermiculating rugæ. An example of the maxilla in the British Museum (Pl. III, Fig. 13) bears a regular series of slender, conical teeth, somewhat bent or uncinate, and of nearly uniform size. This specimen and some mandibular rami are labelled *Sauropsis mordax* on the authority of Agassiz. An outline-figure of the mandible, wanting the presymphysial bone, has already been given by Phillips (Fig. V, Nos. 5, 6); and another example, in the British Museum, is more satisfactorily represented in Pl. III, Fig. 14. The single inner series of very fine teeth upon the splenial bone is

* Smith Woodward, 'Ann. Mag. Nat. Hist.' (6), Vol. i (1888), p. 355.

seen both in Phillips' figure and in some specimens in the British Museum (*e.g.*, No. P. 877*a*); and the anterior third of the dentary bone is also provided with relatively small, closely-arranged, styliform teeth, while these are followed posteriorly by four or five large, widely-spaced, broad, conical teeth, which occupy about another third of the alveolar border. The splenial and dentary bones are abruptly truncated in front for the articulation of the characteristic presymphysial bone (outlined in Fig. 14); but the writer has not yet detected any examples of this element among Stonesfield fossils. A scale, either of *Aspidorhynchus* or *Belonostomus*, is shown in Pl. III, Fig. 15.

The species of *Aspidorhynchus* thus imperfectly indicated appears to be distinguished from known forms by the very gradual slope of the cranial roof to the rostrum, and by the relatively large size, breadth, and fewness of the posterior mandibular teeth. It is the earliest undoubted member of the genus hitherto recorded, and may be named *Aspidorhynchus crassus*.

Genus *Belonostomus*, Agassiz.

The genus *Belonostomus* is closely related to *Aspidorhynchus*, but may be distinguished from the latter by the upper and lower jaws being of equal length. The presymphysial bone is also characteristic from the circumstance that it is very long and united to the rami of the lower jaw by a <-shaped suture; and a fossil possibly exhibiting this suture, figured by Professor Phillips (Fig. V, No. 4), seems to prove that either *Belonostomus* or *Belonorhynchus* occurs in the Stonesfield Slate. Moreover, some portions of elongated skulls, relatively broader and rounder than those referred to *Aspidorhynchus crassus*, have also been found in the same stratum (Fig. V, No. 7); and it will be convenient to adopt Agassiz' undefined name of *Belonostomus leptosteus* for these fossils until some evidence as to the nature of the trunk of the fish shall have been discovered.

The bone named *Belonostomus flexuous* by Phillips (Fig. V, No. 3), is not improbably a maxilla of *Aspidorhynchus crassus*.

Genus *Mesodon*, Heckel.

Numerous portions of the dentition and a few scales of Pycnodont fishes occur in the Lower Oolites, and some have been described, figured, or briefly noticed by Prevost, Buckland, Agassiz,

and Phillips. Employing the generic names in their original comprehensive sense, Agassiz referred most of these remains to *Pycnodus* and *Gyrodus*, though instituting the distinct genus, *Gyronchus*, for one form of upper jaw, characterized by the antero-posterior elongation of the teeth. More recent researches, however, have proved that the jaws assigned to *Pycnodus* pertain to fishes differing so much from the typical *Pycnodus platessus* of the Italian Eocene—the species which first received this generic name—that it is desirable to regard them as representing a separate genus, termed *Mesodon*;* and the so-called *Gyrodus* of the Lower Oolites is also probably to be placed here. This is a characteristic Jurassic fish, ranging from the Lower Lias upwards, and even represented in the Purbeck Beds. As shown by complete specimens discovered in the Bavarian Lithographic Stone, the trunk is relatively circular and deep; the tail is short, not elongated as in *Pycnodus*; the tail-fin is not forked, but abruptly truncated; the expansions of the neural and hæmal arches, which serve the purpose of vertebræ, are not so well developed as in the Eocene genus; and instead of only three rows of teeth on each side of the lower jaw, there are, at least, four or more, sometimes even eight.

From the evidence furnished by jaws, Agassiz originally determined the occurrence of nine species of *Pycnodus* and one of *Gyrodus* in the English Lower Oolites, providing all with names, though only publishing figures and descriptions of six. *Gyronchus oblongus* was an additional form, and some isolated scales were briefly recorded under the name of *Gyrodus perlatus*. A study of the original specimens, in connection with many obtained since the time of Agassiz' researches, and especially in the light of discoveries on the Continent, suggests a very considerable reduction of this list; and the present writer is unable to recognize more than five well-defined specific types, of which four are referable to *Mesodon*, while the fifth may be either *Mesodon* or *Microdon*.

Mesodon Bucklandi is founded upon a portion of vomer, or tooth-bearing bone of the upper jaw, obtained from the Stonesfield Slate, and now in the Oxford Museum. A more satisfactory specimen from the same formation in the British Museum is shown in Pl. III, Fig. 20; and another example, almost detached from

* A. Wagner, 'Abh. k. bay. Akad. Wiss.,' Cl. ii, Vol. i (1851), p. 56.

matrix, from the Great Oolite of Northampton, forms the subject of Pl. III, Fig. 21. The teeth are all well spaced; those of the median series, except quite anteriorly, are less than twice as broad as long; those of the inner lateral series are rounded, and not regularly alternating with the teeth of the other rows; and those of the outer lateral series are much the smallest, with a tendency towards antero-posterior elongation. A few rare, scattered, small teeth also occur between the median and inner lateral series, or are sometimes intercalated between the large teeth of the median series itself. The undescribed type specimen of *Pycnodus obtusus* (Pl. III, Fig. 22), now in the British Museum, seems to be the hinder portion of a similar vomerine dentition; and the so-called *Pycnodus ovalis* may be regarded as the anterior half of the same. All these fossils were obtained from the Stonesfield Slate, and it is interesting to observe that there occur in the same formation examples of a mandibular dentition corresponding in size to the vomer just described, and likewise characterized by the considerable width of the spaces between the teeth. This form of dentition was provisionally separated from "*Pycnodus*" *Bucklandi* by Agassiz under the specific name of *didymus*; but there seems to be no justification for this arrangement, and it has already been suggested as more philosophical to correlate the upper and lower jaws presenting so many points of similarity until absolute proof of their connection or otherwise is obtained. In the mandibular dentition referred to, the teeth of the principal series are almost or quite twice as broad as long; there is a single innermost row of very small, rounded teeth, and there are three regular outer series, of which the second only equals the innermost row in size, while the first is slightly larger, and the third or outermost much larger than all, except the principal series. The scales named *Gyrodus perlatus* by Agassiz, also met with in the Stonesfield Slate, are superficially tuberculated, exactly as in the typical *Mesodon*, and they correspond so closely in size with the adult *M. Bucklandi*, as represented by the jaws, that it is not improbable they, too, may pertain to the same fish. The type specimens are now in the British Museum, and shown in Pl. III, Figs. 30, 31.

Mesodon rugulosus, like the species just described, is also founded upon a vomer in the Oxford Museum.* This was obtained from

* An early figure of a similar fossil is given by C. Prevost, 'Ann. Sci. Nat.,' Vol. iv (1825), Pl. xviii, Fig. 18.

the Lower Oolites between Sulgrave and Culworth, Northamptonshire, while specimens that appear to the present writer specifically identical have also been met with in the Stonesfield Slate, and the Great Oolite of Northampton and of Hampton Court, Gloucestershire. The finest of these fossils is in the collection of Mr. Thomas Jesson, F.G.S., and is shown in Pl. III, Fig. 24. Some of the teeth exhibit the faint striations radiating from an apical pit or ring-like groove, noted in the original diagnosis by Agassiz; but very slight abrasion suffices to obliterate such markings, and the character cannot thus be quoted as distinctive. The teeth are closely arranged, and most of those of the median series are nearly twice as broad as long, their breadth being about equal to that of the two lateral series together. The lateral teeth are larger in proportion to the median series than in *M. Bucklandi*; those of the inner lateral series are rounded, or broader than long, and somewhat larger than those of the outer series, which exhibit a tendency to antero-posterior elongation; and there are usually indications of a minute third lateral series (Pl. III, Fig. 24*a*) below the level of the others, placed on the side of the bone, though equally functional, as proved by their worn crowns. Irregularities sometimes occur, and the specimen shown in Pl. III, Fig. 25, from the neighbourhood of Northampton, is doubtless to be interpreted as an abnormally developed vomerine dentition of the same species. Examples of lower jaws from Stonesfield differ from those assigned to *M. Bucklandi*, in the same respects that the vomer of *M. rugulosus* is distinguished from that of *M. Bucklandi*; and there is thus much probability of their pertaining to the species now under consideration. One of these specimens, in the British Museum, is labelled by Agassiz and Egerton as the undescribed type of *Pycnodus parvus*, and it is shown in Pl. III, Fig. 23. The undefined *Pycnodus latirostris* is founded upon a mandibular dentition of the same form (Pl. III, Fig. 27). It is also not improbable that the vomer described as *Gyrodus trigonus* is merely an unabraded example of the upper dentition, which bears the name of *Mesodon rugulosus* when less satisfactorily preserved; and the vomer assigned to *Gyronchus oblongus* by Phillips seems to be of the same character.

Portions of lower jaws in the British Museum indicate the occurrence of other species of *Mesodon* in the English Lower Oolites, and two of these are shown in Pl. III, Figs. 28, 29. The

first was obtained from the Great Oolite of Little Gibraltar, near Oxford, and is the undescribed type specimen of *M. biserialis*. The teeth are closely arranged, and those of the principal series are about twice as broad as long; the inner row is relatively minute, and there are only two outer series, of which the marginal consists of teeth smaller and rounder than those of the other immediately adjoining the principal one. The second species (Pl. III, Fig. 29), which is apparently new, and may be named *M. latidens*, is characterized by the lateral elongation, and the arched and inwardly tapering form of the principal teeth, which are flanked by a single inner series, and from two to four outer series of relatively minute teeth. The outer teeth are very irregularly arranged posteriorly, but gradually pass into two regular series in front. The apical pittings of the teeth are distinct, and some are as coarsely crenulated as those of the typical *Gyrodus*.

One other fossil possibly referable to *Mesodon*, though exhibiting some features suggestive of *Gyrodus* and *Microdon*, is also worthy of mention. This is the vomer shown in Pl. III, Fig. 32, obtained from the Great Oolite of Little Gibraltar, and now in the British Museum. The form of the bone is sufficiently well preserved to determine its nature without any doubt, and the specimen was originally named *Pycnodus discoides* by Agassiz, though never described. All the teeth are characterized by their circular outline; and the principal median series is relatively smaller than in the typical species of *Mesodon*, thus exhibiting some approach towards *Gyrodus*. There is a tendency towards the alternation of pairs of small teeth with the principal median teeth, as in *Microdon*, but the two ordinary outer series are also present in addition on each side. The generic determination of this unique fossil is thus somewhat doubtful, and further discoveries are required to decide its true affinities.

As remarked by v. Zittel,* the vomer from Stonesfield, named *Gyronchus oblongus* by Agassiz, is probably referable to *Mesodon*.

Genus *Scaphodus* [? Agassiz MS.]

According to Morris,† a Pycnodont jaw from the Stonesfield Slate in the Bristol Museum is labelled by Agassiz with the MS. name of *Scaphodus heteromorphus*. Mr. Edward Wilson, however,

* 'Handb. Palæont.,' Vol. iii (1887), p. 247.
† 'Catalogue of British Fossils,' ed. 2 (1854), p. 344.

points out to the present writer that this is a mistake, and that "the label *Scaphodus heteromorphus*, in Mr. Etheridge's writing, is now pasted across the back of the tablet bearing *Gyronchus oblongus*."* A portion of the right mandibular dentition of a Pycnodont, also from the Stonesfield Slate, is labelled with the same name in the Woodwardian Museum, Cambridge, though on unknown authority; and this specimen (Pl. III, Fig. 33), considered in connection with a small fossil in the Oxford Museum (Plate III, Fig. 34), seems to justify the definition and provisional adoption of some such specific and generic name. The Cambridge fossil is much abraded, exhibiting the principal series of mandibular teeth, with two teeth of the small inner series and two of the outermost series, all in position; the Oxford fossil, on the other hand, consists only of three principal teeth and three of the inner series, though, as shown by the enlarged figure, these are valuable on account of their not being abraded. The principal teeth are transversely elongated and triangular in form, the apex directed inwards; and the coronal surface is very suggestive of that of the upper molars of some Mesozoic mammals. There is a coronal tubercle or eminence at each extremity of these teeth, and a faint longitudinal mesial groove is also sometimes distinguishable. It is not unlikely that the fossils will eventually prove to belong to *Mesodon;* but the name *Scaphodus heteromorphus* (abnormal boat-tooth) is very appropriate, and its temporary use seems expedient.

Genus *Ctenolepis*, Agassiz MS.

Large, round scales, of uncertain relationships, are often met with in the Stonesfield Slate, and there is an especially fine series in the British Museum. One example was figured by Prevost in 1825;† others received the undefined name of *Ctenolepis cyclus* in 1843;‡ and another was figured under this name by Phillips§ in 1871. Each of these scales is very deeply overlapped; the anterior border is ragged, a few radiating grooves extending to it from the centre of the scale; the relatively small, exposed area is invested with smooth ganoine, exhibiting sparse punctations; and

* Agassiz quotes *Gyronchus (Scaphodus) oblongus* in the table on p. xlii of the first vol. of the 'Poiss. Foss.'

† 'Ann. Sci. Nat.,' Vol. iv (1825), Pl. xviii, Fig. 21.

‡ Agassiz, 'Poiss. Foss.,' Vol. ii, Part II (1843), p. 180 (name only).

§ 'Geol. Oxford,' p. 182, Fig. 41, Nos. 1-4.

the hinder border is either entire or only feebly crenulated. By Agassiz these scales were compared with those of *Cœlacanthus*, but, according to the latest researches, it seems more probable that they represent some unknown fish allied to the Teleostean-like Leptolepidæ.

List of Fossil Fishes of the English Lower Oolites.

The following list of species occurring in the English Lower Oolites results from the considerations detailed in the foregoing paper and in the previous publications quoted. The synonymy and remarks are printed in small type :—

Selachii.

Acrodus leiodus, A. S. Woodw.
„ *leiopleurus*, Ag.
Asteracanthus acutus, Ag.
„ *semisulcatus*, Ag.
Asteracanthus tenuistriatus, Phil.
Hybodus apicalis, Ag.
„ *dorsalis*, Ag.
„ *grossiconus*, Ag.
„ *levis*, A. S. Woodw.
[May be *Nemacanthus*.]
„ *marginalis*, Ag.
„ *polyprion*, Ag.
Hybodus jugosus, Phil.
Nemacanthus brevis, Phil.
Nemacanthus brevispinus, Ag.
Strophodus lingualis, Phil.
„ *magnus*, Ag.
Strophodus favosus, Ag.
„ *tenuis*, Ag.

Chimæroidei.

Ganodus Bucklandi, Egert.
„ *dentatus*, Egert.
„ *falcatus*, Egert.

Ganodus neglectus, Egert.
„ *Oweni*, Ag.
[May include *falcatus*, *neglectus*, and *psittacinus*.]
„ *psittacinus*, Egert.
„ *rugulosus*, Egert.
Ganodus curvidens, Egert.
Ischyodus Colei, Ag., sp.
Chimæra (*Ganodus*) *Colei*, Ag.
„ *emarginatus*, Egert.
Leptacanthus serratus, Ag.
„ *tenuistriatus*, Ag.
[Probably spines of *Ganodus*.]

ICHTHYODORULITE.

Pristacanthus securis, Ag.

DIPNOI.

Ceratodus Phillipsi, Ag.

GANOIDEI.

Aspidorhynchus crassus, A. S. Woodw.
Sauropsis mordax, Ag.
Belonostomus flexuous, Phil.
Belonostomus leptosteus, Ag. MS.
Caturus pleiodus, Ag. MS.
Ctenolepis cyclus, Ag.
Gyronchus oblongus, Ag.
[Probably *Mesodon*.]
Lepidotus unguiculatus, Ag.
Pycnodus rudis, Phil.
„ *tuberculatus*, Ag.
[Probably suboperculum of *L. unguiculatus*.]
Leptolepis disjectus, A. S. Woodw.
Macrosemius brevirostris, Ag. MS.
Mesodon biserialis, A. S. Woodw.
„ *Bucklandi*, Ag., sp.
Pycnodus Bucklandi, Ag.
„ *didymus*, Ag.
„ *obtusus*, Ag.

Pycnodus ovalis, Ag.
(?) *Gyrodus perlatus*, Ag.
Mesodon (?) *discoides*, A. S. Woodw.
Pycnodus discoides, Ag.
„ *rugulosus*, Ag., sp.
Pycnodus rugulosus, Ag.
„ *parvus*, Ag.
„ *latirostris*, Ag.
Gyrodus trigonus, Ag.
„ *tenuidens*, A. S. Woodw.
„ *umbonatus*, Ag., sp.
Pycnodus umbonatus, Ag.
Ophiopsis Flesheri, Ag., sp.
Pholidophorus Flesheri, Ag.
Pholidophorus? minor, Ag.
Scaphodus heteromorphus, A. S. Woodw.

EXPLANATION OF PLATE III.

FIG. 1.—*Nemacanthus brevis*, Phil.; dorsal fin-spine, lateral aspect. Stonesfield Slate. (B.M., No. P. 2,218.)

FIG. 2.—*Pristacanthus securis*, Ag.; portion of spine, lateral aspect. Stonesfield Slate. (Mus. Roy. Coll. Surgeons.)

FIG. 3.—*Ischyodus* sp.; coronal aspect of right palatine dental plate imperfect anteriorly. Gt. Oolite, near Northampton. (T. Jesson Collection.)

FIG. 4.—*Ganodus* sp.; coronal aspect of left palatine dental plate. Stonesfield Slate. (B.M., No. P. 1,133.)

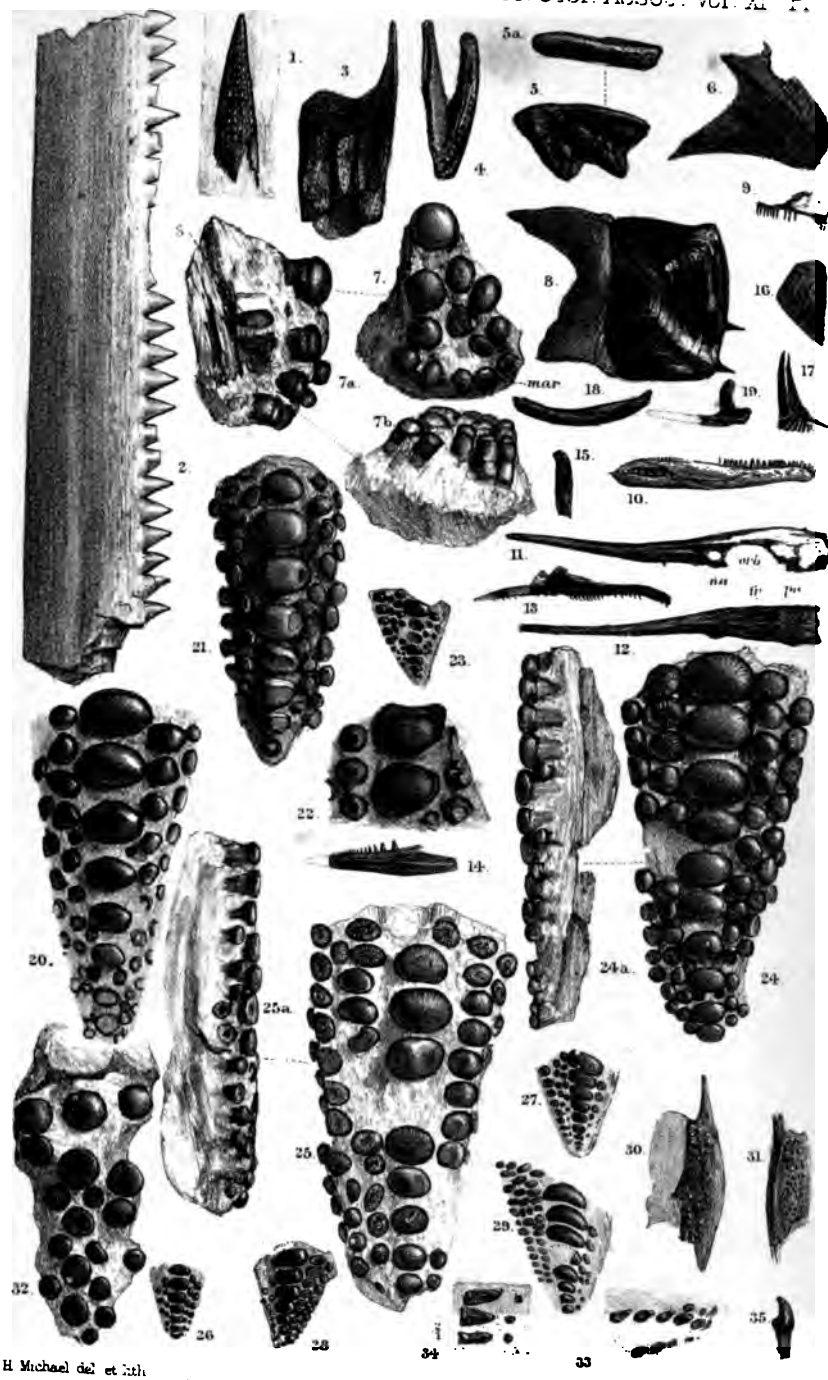
FIG. 5.—*Ceratodus Phillipsi*, Ag.; imperfect tooth, coronal aspect, and (5*a*) inner view. Gt. Oolite, near Northampton. (T. Jesson Collection.)

FIG. 6.—Right pterygo-quadrate bone of a Cœlacanth Ganoid, inner aspect. Stonesfield Slate. (B.M., No. P. 4,277.)

FIG. 7.—*Lepidotus unguiculatus*, Ag.; portion of mandibular dentition, coronal aspect, with view of transverse fracture (7*a*) and anterior view (7*b*). *s.* successional tooth, partially upturned. *mar.* marginal teeth. Gt. Oolite, near Oxford. (Oxford Museum.)

FIG. 8.—Ditto; scale. Gt. Oolite, near Northampton. (T. Jesson Collection.)

FIG. 9.—*Macrosemius brevirostris*, Ag. MS.; maxilla, lateral aspect. Stonesfield Slate. (B.M., No. P. 3,617.)



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LOWER JURASSIC FISH-REMAINS.

Mintern. Bros. imp.

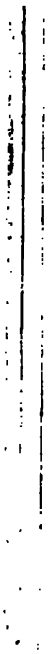


FIG. 10.—*Caturus pleiodus*, Ag. MS.; mandibular ramus, outer aspect. Stonesfield Slate. (B.M., No. P. 902.)

FIGS. 11, 12.—*Aspidorhynchus crassus*, A. S. Woodw.; two examples of the skull, dorso-lateral aspect. *fr.* frontals. *na.* nasal opening. *orb.* orbit. *pa.* parietals. Stonesfield Slate. (B.M., Nos. 39,199, 39,200.)

FIG. 13.—Ditto; maxilla, lateral aspect. Stonesfield Slate. (B.M., No. P. 3,720.)

FIG. 14.—Ditto; left mandibular ramus, outer aspect. Stonesfield Slate. (B.M., No. P. 3,720*a*.)

FIG. 15.—Ditto (?); scale, outer aspect. Stonesfield Slate. (Oxford Museum.)

FIGS. 16-19.—*Leptolepis disjectus*, A. S. Woodw.; operculum, preoperculum, maxilla, and dentary, outer aspect. Stonesfield Slate. (B.M., No. P. 959*a*.)

FIG. 20.—*Mesodon Bucklandi* (Ag.); upper dentition, coronal aspect. Stonesfield Slate. (B.M., No. P. 1,640.)

FIG. 21.—Ditto; ditto. Gt. Oolite, near Northampton. (T. Jesson Collection).

FIG. 22.—Ditto; fragment of ditto. Stonesfield Slate. (B.M., No. P. 525.)

FIG. 23.—*Mesodon rugulosus* (Ag.); right lower dentition of young, coronal aspect. Stonesfield Slate. (B.M., No. P. 522.)

FIG. 24.—Ditto; upper dentition, coronal aspect, and (24*a*) side view. Gt. Oolite, near Northampton. (T. Jesson Collection.)

FIG. 25.—Ditto; ditto, coronal aspect, and (25*a*) side view. Gt. Oolite, near Northampton. (T. Jesson Collection.)

FIG. 26.—Ditto; ditto, coronal aspect of young. Stonesfield Slate. (B.M., No. P. 521.)

FIG. 27.—Ditto; right lower dentition of young, coronal aspect. Stonesfield Slate. (B.M., No. P. 3,780.)

FIG. 28.—*Mesodon biserialis*, A. S. Woodw.; left lower dentition, coronal aspect. Gt. Oolite, near Oxford. (B.M., No. P. 523.)

FIG. 29.—*Mesodon tenuidens*, A. S. Woodw.; right lower dentition, coronal aspect. Stonesfield Slate. (B.M., No. 47,983.)

FIGS. 30, 31.—Scales of *Mesodon*. Stonesfield Slate. (B.M., No. P. 520.)

FIG. 32.—*Mesodon (?) discoides*, A. S. Woodw.; imperfect upper dentition, coronal aspect. Gt. Oolite, near Oxford. (B.M., No. P. 524.)

FIG. 33.—*Scaphodus heteromorphus*, A. S. Woodw.; portion of right lower dentition, coronal aspect. Stonesfield Slate. (Woodwardian Museum, Cambridge.)

FIG. 34.—Ditto; three unabraded teeth of two inner series of lower dentition, twice nat. size. Stonesfield Slate. (Oxford Museum.)

FIG. 35.—Anterior prehensile tooth of Pycnodont, side view. Gt. Oolite, near Northampton. (T. Jesson Collection.)

B.M. = *British Museum. Except No. 34, all the figures are of the natural size.*

Notes on the Nature of the Geological Record.

By T. V. Holmes, F.G.S.

(Being the Presidential Address delivered February 7th, 1890.)

It appears to me that in these days of ever-increasing specialism a Presidential Address is never more useful than when it deals with those broad elementary questions of which the specialist is too apt to lose sight. I therefore propose to discuss on this occasion various points which have interested me in connection with the nature of the geological record; to consider both the character of the evidence it affords and the gaps in it, whether resulting from unconformities between different beds or from the narrow range of the fossil remains the sedimentary rocks may contain.

Fifteen or sixteen years ago it was generally supposed that the Globigerina Ooze of the Atlantic was so nearly identical with Chalk that the latter might be considered as a deep-sea formation, the deposition of which had been going on continuously since Cretaceous times in the deeper parts of the ocean. But further examination showed that the fauna of the deposits of Globigerina Ooze from comparatively shallow water much more resembled that of the Chalk than did the organic remains obtained from the deep sea; and it was established by Dr. Gwyn Jeffreys* and others that the fossils of the Chalk pointed to its deposition in a comparatively shallow sea, though at a considerable distance from any land, and consequently beyond the area in which sands, clays, and other shore deposits were being formed. It was further shown that the sands and clays now found directly below the Chalk, but which may have been forming near the shore while the Chalk itself was being deposited further out at sea, show an assemblage of fossils with much general resemblance to those of the Chalk. In short, that formation, which used to be considered one of the best examples of a deep-sea deposit, and as testifying to the former extension of the Atlantic Ocean, with a depth of 1,000 to 2,000 fathoms, over what is now central Europe, is now known to imply only the existence in Cretaceous times of a comparatively shallow

* 'Rep. Brit. Assoc.,' 1877.

sea, somewhat larger than the Mediterranean,* and with a depth not necessarily exceeding 250 or 300 fathoms.

With this view as to the origin of the Chalk there has grown up a fuller recognition of the fact that the great masses of sedimentary rock of Palæozoic age show in their ripple-markings, annelid-burrowings, and desiccation cracks, evident signs of deposition in shallow water. In fact, there is nothing but the great thickness of some of these formations to suggest that they are not simply shore deposits; and, on consideration, this great thickness is seen to offer no real difficulty; for all it really necessitates is the gradual sinking of the area in which deposition is taking place at a rate nearly equal to that of the growth of the deposit. Thus it may be said that one of the most recent developments of geological thought has been the recognition of the various marine formations as deposits formed in more or less shallow water, whether near to or far from the shore. This view implies the acceptance of the opinion, which for long gained little ground among geologists, of the general permanence of continental areas as mainly land and of deep oceanic basins as ocean. Whatever may have been the case in the very earliest periods of the earth's history, this would seem to be true of the ages that have passed away since the beginning of the geological record. It may, however, occur to many persons to remark that though what are now deep-sea basins of 1,000 fathoms or more, may always have been deep seas, yet that every part of every existing continent must have been more than once under water; and this has evidently been the case. But all that is meant by the permanence of continental areas as mainly land is that at no time has land now part of a continent been deep sea of 1,000 fathoms or more, though considerable portions of its surface may have been covered again and again by seas of from 50 to 500 fathoms or thereabouts. Thus, what is now a compact and solid continent must have consisted at many different periods of two or more parts too large to be called islands, with many smaller islands of various sizes grouped around the larger masses. In the Eocene period, Mr. A. R. Wallace informs us,† tropical Africa was cut off from Europe and Asia by a sea stretching from the Atlantic to the Bay of Bengal, Northern Africa being then included in the Eurasian

* See Wallace's 'Island Life.'

† 'Island Life,' p. 390.

continent ; and in Cretaceous times, as we have seen, Europe, cut in two by the sea in which the Chalk was deposited, was rather a cluster of islands than a continent. Indeed, we may recall the remark of Darwin* that he agrees with Mr. Godwin-Austen that "the present condition of the Malay Archipelago, with its numerous large islands separated by wide and shallow seas, probably represents the former state of Europe, whilst most of our formations were accumulating."

And if, from oceans and continents we turn to an area of midland seas, like that now occupied by the Mediterranean, Black, and Caspian, we find evidence of a similar combination of permanence with variations. At one time Europe (Sir A. C. Ramsay tells us)† was in all probability completely separated from Asia, the Black, Caspian, and Aral seas being united, and the whole having an outlet connecting them with the Arctic Ocean east of the Ural Mountains, along what are now the valleys of the Tobol and the Obi. At another period the Mediterranean had no outlet into the Atlantic at Gibraltar, the isthmus of land then connecting Europe and Africa allowing an interchange of mammalia at that point. This took place, we learn from Sir A. C. Ramsay, probably during an interglacial episode of the Glacial Period. Subsequently this isthmus was again submerged, and with it the Rock of Gibraltar, to a depth of at least 700 feet. After this a re-elevation occurred, which again appears to have been sufficient to permit the passage of mammals ; and it is highly probable that, either at the periods of elevation just mentioned or at others, there was a passage across what is now shallow sea between Sicily and Tunis, which was doubtless found of service by migratory animals. On the other hand a physical map of the Mediterranean and Black Seas shows that it is very unlikely that the areas now occupied by them have been wholly or mainly land for an immense period. For the central part of the Black Sea is more than 1,000 fathoms in depth, while most of it varies between 100 and 1,000 fathoms. In the Mediterranean the proportion of deep water is much greater. An elevation of the whole area to the height of 6,000 feet, which would make dry land of the Adriatic and Ægean Seas, join Cyprus to Syria, and connect both Sicily and Sardinia with Italy and Africa,

* 'Origin of Species,' Chap. IX.

† 'Europe,' by F. W. Rudler and G. G. Chisholm. Edited by Sir A. C. Ramsay, Lond., 1885.

as well as close the Straits of Gibraltar, would yet leave a great lake occupying most of the surface between Sicily and Egypt, another between Italy and Sardinia, and a third between Sardinia and Spain.

Thus a full recognition of the truth of the view that continental land areas have always been mainly land and that deep oceans have remained sea since the beginning of the geological record, does not exclude variations in sea and land amply sufficient to allow of the deposition of the Chalk and other comparatively pure limestones, in addition to the beds generally recognized as shallow-water or shore deposits. Similarly, though broad areas of depression within a continental area, like that occupied by the Mediterranean, Black, and Caspian Seas, may have been mainly areas of depression through many geological ages, they have varied so much in character from time to time as to allow of the most important changes in physical geography, and consequently in the fauna and flora of the adjacent land-areas. Centres of elevation, also, though equally persistent, and dating their origin from Palæozoic times, may, as in the case of the Alps, have had many upliftings and depressions since, and have even been largely under water as late as the Eocene Period.

Perhaps the most important confirmation of this view of the general permanence of continental and oceanic areas is afforded by the present distribution of animal and vegetable life in the islands, large and small, which are found at various distances from the continents. Mr. A. R. Wallace, in his admirable 'Island Life,' has shown how decidedly the resemblance of the animals and plants of an island to those of the nearest continent varies not merely with distance but also with the depth of the sea between them. For of course, on the theory of the permanence of continental and oceanic areas, the separation of an island by a deep sea of 1,000 fathoms or more makes it very unlikely that it was ever united to a continent; a sea varying between 250 and 500 fathoms makes it probable that connection must have been only at some remote period; while a sea of 100 fathoms or less suggests union at a comparatively recent date.* It will be best to illustrate the matter by considering briefly the cases of three islands or island

* Of course any figures are but approximate; upheavals and depressions during any given period having been much greater and more frequent in some areas than in others.

groups, one Britain, which may be classed as recently continental, a second, Madagascar, as remotely continental, and a third, St. Helena, as oceanic.

In the case of the British Isles we find, in the first place, that an elevation of the whole area to the amount of 100 fathoms or 600ft. would not merely join them to the Continent and connect Ireland with Britain, but that the new land would extend outside Western Ireland and the Hebrides so as to include the Orkney and Shetland Isles. All that is now sea between Denmark and Brittany would then be land. Secondly, the rocks composing the British Isles are simply westerly extensions of those of the continent, and the indigenous fauna and flora are almost identical. In short, all the facts testify to a former connection and a very recent separation. But if we turn to Madagascar we notice that though the sea between Madagascar and Africa is decidedly shallower than that east of the great island, yet that it is much deeper than that between Britain and the Continent, being mainly over 100 fathoms in depth. Indeed, an elevation of the sea bottom between Africa and Madagascar to the extent of 600ft. would only serve to enlarge the areas and increase the number of the Comoro Islands, making it easier for birds to cross, while land mammals would find the task almost as impracticable as ever. As regards the rocks, the Rev. R. Baron, in his recent paper on the geology of Madagascar,* says that there are some which, when referred to the European standard of geological chronology, would be classed as Jurassic, Cretaceous, Eocene, and Recent. Mr. Wallace tells us that there are 66 species of mammals in this island, a fact pointing to its former connection with the Continent. But 33 out of these 66 species consist of lemurs, which are nowhere so abundant as in Madagascar; there are a dozen species of Insectivora; the Carnivora are represented by a peculiar cat-like animal, and by eight species of Civet-cats. There are also a river-hog, a small hippopotamus, and some rats and mice. Thus all the lions, hyænas, elephants, rhinoceroses, giraffes, zebras, baboons, and other animals characteristic of Africa are entirely absent, a fact which, apart from others telling in the same direction, tends to show that there has been no land-connection between Africa and

* 'Quart. Journ. Geol. Soc.,' Vol. xlv, p. 305 (1889).

Madagascar since a very remote period, and confirms the inference drawn from the depth of the sea between them.

St. Helena is a good example of what is termed an oceanic island. It is situated more than 1,100 miles from the coast of Africa and 1,800 from that of South America. We learn from Mr. Wallace that it is about ten miles long and eight broad, and that it is composed wholly of volcanic rocks. It is mountainous, and is bounded by stupendous precipices. Its highest point is 2,700ft. above the level of the sea. Everything indicates that it is simply a volcanic mass that has been built up from the depths of the ocean, and that it has never been much larger than it now is. The depth of the ocean for hundreds of miles around it varies between 2,000 and 3,000 fathoms. It was discovered by the Portuguese in the year 1502. There are no indigenous mammals, reptiles, fresh-water fishes, or true land birds. When discovered, it was densely covered by luxuriant vegetation; but the introduction of goats shortly afterwards caused its almost entire destruction, so that the island is now barren and bare. The native flora is of very ancient type. There are many species of insects. Of the Coleoptera there are 203 species, but of these 74 are common and widely diffused, and were probably introduced by man. Of the remaining 129, which are believed to be aboriginal, all but one are found nowhere else. These facts point to their great antiquity, which has allowed time sufficient for their modification and adaptation to this remote island. They probably date back from Miocene or still earlier times. As a large proportion of the St. Helena beetles live, even in the perfect state, within the stems of plants and trunks of trees, they probably came over chiefly in drift-wood.

It would be easy to take other examples, with similar results. Of course, in many instances there is something special—something which seems at first sight difficult to explain; but it seems to me that it would be almost impossible to mention a case seriously antagonistic to the view held by Mr. Wallace and others, that continental areas have been permanently land or shallow-water, and oceanic areas deep-water, since the beginning of the geological record.

I think the general opinion would be much more decidedly in favour of the Darwinian theory if the number and importance of the gaps

in the geological record of past life were more fully realized. It is not that there is any fault to be found with the doctrines on this subject as they are laid down in our text-books; but that our practical belief in the importance of the missing information is apt to be absurdly small. It is acknowledged, with the lips only in too many cases, just as some of us recognize that "there are more things in heaven and earth than are dreamt of in our philosophy," and straightway proceed to talk and write as though future workers would have little but detail to occupy them.

The imperfection of the geological record is many-sided. Besides the absence of evidence here and there, as shown by the unconformities between different formations, the evidence afforded by a fossiliferous bed itself is necessarily of an extremely partial description. A marine formation, as a general rule, contains simply the remains of marine creatures whose hard parts allow of their preservation, the bones of land-animals (if any) being there as the result of what may be called accident. If, on the other hand, we turn to terrestrial, lacustrine, or river formations, we are equally far from an assemblage of fossils fairly representing the life of the period. Hence, as experience has so often shown, the extremely small weight due to merely negative evidence.

In Darwin's well-known chapter on the "Imperfection of the Geological Record" the illustrious author notes the enormous destruction of rock through denudation, the great periods of time that have often elapsed between the deposition of the uppermost beds of one formation and those of the lowest beds of its successor, and also the evidence that each separate formation has been intermittent in its accumulation. His observations had convinced him that nearly all thick fossiliferous formations must have been formed during the subsidence of a shallow sea-bottom—not as deposits beginning in profound depths of the sea; and he remarks that he had been much struck by the fact that an examination of many hundred miles of the South American coast (which has been elevated several hundred feet during the Recent Period) showed the absence of any Tertiary or Recent deposits sufficiently extensive to last for even a short geological epoch. These formations were gradually worn away by the action of the waves as soon as they attained a certain level, and either destroyed or only slight fragments preserved. Having been formed on a sea-bottom that was gradually rising, they necessarily could not attain

the thickness necessary to enable them to endure, without almost entire destruction, the fury of the waves during their upheaval.

But it is evident that even in the case of a very thick deposit, situated as were those mentioned by Darwin, destruction of the upper beds would go on at the same rate as in a thin formation of the same material. The lower beds, having the advantage of being more consolidated, would offer more resistance to erosion, and might be to some extent preserved. Thus it seems inevitable that a considerable destruction of the upper beds must occur where any area is being elevated, and is during elevation exposed to the waves of an open sea. The strata thus removed may be re-deposited in other places, but they will be found in the newer deposits they have helped to form, mixed with other coast material of various ages but similar lithological character, and having usually lost their fossils. If, as Darwin remarks, "it has been observed by more than one palæontologist that very thick deposits are usually barren of organic remains except near their upper or lower limits," it is evident that this denudation of the upper beds of thick formations during their emergence must be a most important influence in increasing the imperfection of the geological record.

Of course, denudation of the upper beds of an emerging formation is not more likely to occur than the planing down of the uppermost beds of a subsiding one. In many cases the fact that the older of two formations has become land, and has consequently been exposed to subaerial denudation previous to the submergence that has allowed the deposition of its successor, is at once obvious from the unconformity between them. But occasionally a very decided unconformity has only been shown to exist after much detailed work in the field, and there can be little doubt that many unconformities remain yet undiscovered. A good example of an unconformity revealed only after much field-work is that of the Plumpton Rocks near Knaresborough, which were visited by this Association during the excursion to the West Riding of Yorkshire in 1882. A paper on these beds by the late James Clifton Ward * gives the opinions of various geologists of eminence as to their affinities; from which we learn that Prof. Sedgwick, Prof. Phillips and Sir Roderick Murchison thought (at the date of the

* 'Quart. Journ. Geol. Soc.', Aug., 1869.

paper's appearance) that they were Permian, while Mr. Binney and the Rev. Stanley Tuke inclined to the belief that they were of Millstone Grit age. Ward (who had been working at the Millstone Grit beds in detail for the Geological Survey), after much work in the field, and many visits to places at which colleagues thought he might find evidence bearing on the matter, came at last to the conclusion that the Plumpton Rocks belonged to the Millstone Grit; and there seems to be no doubt as to the correctness of his view; but when we reflect that the three eminent geologists who had entertained the opposite opinion were all men skilled and experienced in field-work, who had formed their opinion after more or less inspection of the locality, and when we also remember that the Permian rocks, which lie unconformably on the Coal-Measures, are necessarily still more unconformable to the underlying Millstone Grit, we see now easily a less decided yet still important unconformity might escape notice, even in Western Europe.

Of course where beds have not been simply raised into land and again submerged, but have also been decidedly tilted during the process, the unconformity of the formation deposited thereon to the strata on which it rests is usually at once manifest. But in many cases formations appear to have been elevated and depressed with much evenness over a large area, and then the detection of an unconformity may be by no means an easy matter. Thin and variable passage-beds might be found here and there, and there might be occasional signs of erosion between the two formations; but on the other hand there would probably be a decided appearance of general conformity between them, the escarpments marking their respective outcrops keeping nearly parallel with each other over considerable breadths of country. In the case of our own Coal-Measures it would seem that the numerous changes of level which took place during their deposition must often have involved more or less denudation of the upper surfaces of the beds, though the evenness with which they have been depressed has usually prevented any recognition of the resulting unconformities. No great amount of rock may have been removed, and yet its removal may have been of the highest importance from a palæontological point of view.

In the 'Geological Survey Memoir on the Yorkshire Coalfield' (Chapter II, Section 1) Prof. A. H. Green gives a general

sketch of the Carboniferous rocks, which contains a much fuller account of the mode of formation of the various deposits than is usual in text-books, and which has the additional advantage of being the result of unequalled practical knowledge of the beds described. As regards the Carboniferous Limestone and Yoredale Beds, I need only say that the Limestone was evidently formed, like the Chalk, in a sea beyond the area occupied by shore deposits, while the Yoredale sandstones and shales, together with the more or less earthy limestones of that age, indicate a shallower sea, and greater nearness to land. The overlying Carboniferous beds, the Millstone Grit and the Coal-Measures, consist almost entirely of shales, sandstones, coals, and underclays, limestone being scarcely ever found. They consequently point to shallow water or terrestrial conditions. Prof. Green remarks on the great irregularity of the sandstones in these upper groups of strata, some having a fairly regular thickness of 100ft. or more for miles, wedging out to nothing in a space of a mile or less. But there is one very coarse sandstone which forms the topmost bed of the Millstone Grit and is called the Rough Rock, which is exceptional in character, as it spreads over hundreds of square miles with a tolerably even thickness. Prof. Green thinks this Rough Rock may have arrived at its present condition in the following way. The water near the shore becoming full of banks of coarse sand, the action of the waves during elevations in which the banks became land, and depressions during which they were beneath the level of the sea, tended to rearrange the material and form a broad deposit of much the same character throughout. Of course changes of this kind would tend to the utter destruction not only of any shallow-water fossils the sandbanks might contain, but of any remains of land animals which might have existed on them during their periods of elevation.

As regards the sandstones generally, Prof. Green remarks that "the junction of a sandstone with the overlying shale is often very uneven, as if part of the original sandbank had been cut away before the shale began to be deposited." In many cases, he adds, "there can be little doubt that the surface of the sandstone bed was for a time a land-surface traversed by streams of running water."

Sandstones being usually deposited in shallower water than shales, it is evident that a slight upheaval would make their tops

into land surfaces. Coals are often found on the top of sandstones, though there is almost always a band of underclay or "spavin" beneath each coal seam. This spavin is sometimes very siliceous, and is then called spavin stone. It is the soil on which the coal-plants grew, and is more or less full of rootlets. Fossilized trunks of trees, still standing erect and attached to their roots, are sometimes seen to rise from an underclay. Thus, a thick bed of coal indicates a considerable period during which the area it occupies was low-lying swampy ground, neither elevated nor depressed to any perceptible degree.

In the Millstone Grit and Coal-Measures the prevalent fossils are land plants, with certain freshwater shells; but occasionally marine shells are found, though rarely, and in thin bands, usually of black shale. In many instances, Prof. Green remarks, "these marine bands form the roof of a coal, and this rather looks as if in these cases the land went down with a small jump, when subsidence recommenced, after the stationary period during which the growth of the coal went on."

As each band of coal with its spavin or underclay marks the existence of a land-surface which lasted for a considerable period, while the overlying shales and sandstones indicate one of depression, it is possible, with the aid of a sheet of the vertical sections of the shafts of various collieries (published by the Geological Survey), to ascertain what oscillations of level took place between any two given horizons. In the Yorkshire Coalfield the two most important coals are the Silkstone and the Barnsley, and they are certainly the best-known in the London market. These coals are on the average about 1,000ft. apart, the Silkstone being the lower of the two. We learn from a sheet of vertical sections arranged so as to illustrate the strata between these two coals in the southern part of the Yorkshire coalfield, that, starting from the Silkstone, we have evidence of at least twelve old stationary land-periods alternating with others of depression, before we reach the Barnsley; and if we consult another sheet of sections showing the beds between the Barnsley and the Wathwood or Melton Field Coal, which lies on the average rather more than 500ft. above the Barnsley Coal, we find that there must have been between them certainly ten stationary periods alternating with others during which there was subsidence. But the 1,500ft. of beds between the Silkstone and Wathwood Coals form only about

two-fifths of the whole of the Coal-Measures—taking the average for the southern part of the district.

Enough has been said to illustrate the numerous changes of level during Coal-Measure times; and we must not forget that by fixing our attention on the coals and underclays alone we underrate the number of these ancient land-surfaces; for, as I have already remarked, the tops of some of the sandstones show signs of having been for a time land-surfaces traversed by streams of running water. This indicates a slight upheaval in each case, while the growth of a coal does not necessarily imply anything more than the silting up of an area to such an extent as to allow plants to grow on its surface. Then the mere growth of vegetation during a stationary interval would allow the formation of a coal-seam. In such a case there would be no planing-down action on the part of the sea on the emergence of the tract as land. But the sandstone land-surfaces must have been more or less denuded both during upheaval and subsequent subsidence; for, as Prof. Green remarks, in a passage already quoted, "the junction of a sandstone with the overlying shale is often very uneven, as if part of the original sandbank had been cut away before the shale began to be deposited."

Now the importance of these facts in their bearing on the Fossil Record seems to me to lie in the following considerations. While coal-swamps might abound in Labyrinthodonts and other reptiles, land mammalia (supposing them to have existed) would mostly have preferred the drier land resulting from elevation of the area, of which we have evidence in these sandstones. Thus in the case of this most terrestrial of formations, the Coal-Measures, land-surfaces on which mammalia might have lived have been eroded away, while those on which reptiles flourished have remained to a great extent, if not wholly, uninjured.

The Permian and Triassic, or, in other words, the New Red Sandstone Series of rocks, are now generally believed to have been deposited in great lakes or inland seas, which varied from time to time in size, in saltness, and in the degree, if any, of their communication with the open sea. Above the highest beds of New Red Sandstone age are the Rhætic Beds, which in Britain vary in thickness from about 20 to 150ft., and form passage beds between the New Red Sandstone series and the Lower Lias. The most persistent portion of these Rhætic (or Penarth) Beds are black

shales, whose most characteristic fossil is the *Avicula contorta*. The late Prof. Edward Forbes considered that the Rhætic fossils much resembled those of the Black and Caspian seas, where there are misshapen forms due to the freshening of the water from the influx of rivers. The Lower Lias strata are entirely estuarine or marine. Sir A. C. Ramsay notes ('Q. J. G. S.,' 1871) that in England "the Lower Lias follow the Rhætic Beds wherever they go," and adds that, "though there are symptoms of erosion between them at Penarth and at Curry Rivell in Somerset, yet the conformity is, on the whole, so complete, that wherever we meet with the base of the Lower Lias we look for the Rhætic Beds below, and as yet we have not been disappointed." But he admits that the transition between Rhætic and Lias forms in these areas is very sudden and difficult to explain.

Besides land-plants, among the very few fossil remains found in the upper beds of the New Red Sandstone Series are those of many species of reptiles, while in the highest beds have been discovered the bones of the earliest British mammal yet known, a small creature of marsupial affinities, the well-known *Microlestes*. The presence of the footprints of the reptiles in the sandy Keuper mud shows that the places at which they were found were not far from land, probably, Sir A. Ramsay thinks, where a moist surface had been left uncovered by water owing to the summer evaporation of a lake; for if left at low tide they would probably have been obliterated in a few hours by the next high tide, whereas exposure to a hot sun for many weeks before they were covered by water would bake and harden them, and immensely increase their chances of preservation. These footprints are found at many places in England, a circumstance which seems to point to the conclusion that in England, towards the close of this period, these lakes were of no great size.

We have seen that Sir Andrew Ramsay notes the strong general conformity of the Lower Lias to the Rhætic Beds, though there are occasional signs of erosion between them. But it seems evident that considering the thinness and variable nature of these beds in England, and their character as passage beds, they might easily be present at two places 100 miles apart, and absent at certain spots between them.

Though in the passage between the uppermost beds of the lacustrine New Red Series and the lowest of the marine Lias we

have probably as near an approach to conformity between two formations of dissimilar kinds as any furnished by our geological record, it is evident that the conformity, if it may be so called, can only be of a broad and general character. For the sinking of the lacustrine area beneath the sea so as to allow of the deposition of the Lias, necessarily involved the planing down of the interlacustrine land on which the Triassic land-plants, reptiles, and mammals lived, and the destruction of any remains of them that may once have been deposited on its surface. Thus the relics of Upper Triassic land-life seem to be those of plants and animals whose remains were borne down into the salt lakes by rivers, especially during floods, together with the footprints of the reptiles which crossed the borders of the lakes when they were at their lowest. If the interlacustrine land-surfaces had not been planed down to the level of the lakes the unconformity between Trias and Lias would have been at once manifest. But the destruction of the Triassic land-surfaces, which has practically increased this unconformity, has at the same time tended very much to impart a delusive appearance of conformity to these two formations.

Though there can hardly be any doubt that mammalia were the last class of creatures to appear on the earth, it is by no means improbable that they may some day be discovered to date from a much earlier period than that of the uppermost beds of the New Red Sandstone Series. Had the earliest mammals been creatures of marine habits, (the land-mammals showing signs of being their modified descendants), we should probably have found their fossil remains in almost as many formations as now show those of fish. But, as we all know, the Cetacea, on the contrary, exhibit every mark of being the much modified descendants of land-mammalia, and consequently are creatures which we could expect to see only at a late period. It seems likely that the lowest division of the Mammalia known to us, the Monotremata, was never very numerous or widely diffused, if we may judge from its extremely restricted range at the present day, its two living representatives, the Ornithorhynchus and Echidna, being confined to Australia, Tasmania, and New Guinea, and their fossil remains to New South Wales. They, in common with the Australian marsupials, probably owe their continued existence to abundance of food, together with the absence, till quite recent times, of any competition with the higher mammalia

But the marsupials, unlike the monotremes, show by their

existence nowadays in countries so remote from each other as Australia and America, and their presence in a fossil state in the Secondary and Lower Tertiary strata of Europe, that they were once very numerous and very widely distributed, having originated in the great Eurasian continent and thence spread to Australia and America, though now supplanted in the land of their birth by the competition of higher forms. All the mammals of the Mesozoic or Secondary period in Western Europe whose remains have yet been discovered have been marsupials, the earliest known at present being the already mentioned *Microlestes*, found in the uppermost beds of the Trias. At the base of the Great Oolite in Oxfordshire and Gloucestershire is the so-called Stonesfield Slate, which consists of calcareous sandstones, having a total thickness of about six feet. These beds, according to the late Prof. Phillips, were probably deposited in a lagoon, with bordering marshes and drier land. The remains found in them are those of small insectivorous marsupials, of insects and of land-plants, together with those of marine mollusca, of fishes, and of reptiles. The Stonesfield Slate is a purely local development, and by no means always found at the base of the Great Oolite; it is chiefly known, says Sir A. C. Ramsay,* east of Cheltenham on the Oolitic plateau, and perhaps attains its greatest thickness near the town of Stonesfield. Of course, being, as its fossils tend so strongly to show, a lagoon deposit, it cannot be expected to spread over a very large area, a circumstance much to be regretted considering its great palæontological interest. Yet what but a lagoon deposit would be likely to contain so rich and varied a fauna, and to retain it unharmed by erosion during subsequent depression. For firstly, in a lagoon we get the occasional free admission of sea-water and marine creatures of all kinds, combined with the proximity of land suited to the habitation of terrestrial reptiles and mammals. Secondly, the remains of land-plants and animals, borne into a lagoon by streams, especially during floods, would largely remain within it, subside tranquilly, be covered quickly in an unusual thickness of sediment, and thus be permanently preserved. If the same remains were brought down to an open shore, they would be much more widely dispersed, be less likely to escape being devoured while floating about, and have much less chance of sinking at a spot where a quick deposit of

* 'Physical Geology and Geography of Great Britain.

sediment was taking place. In treating of the Collyweston Slate, found near Stamford in Lincolnshire, which is sometimes 18 feet thick, or three times as thick as the Stonesfield Slate, Mr. H. B. Woodward remarks* that the general resemblance between the Collyweston Slate and the Stonesfield Slate, caused them at one time to be confounded. But though the Collyweston Slate contains marine fossils and numerous plant-remains, and shows in ripple-markings, worm-tracks and burrows that it was deposited close to the shore, neither reptiles nor mammals have been found in it; and considering the lithological resemblance between the two formations and their common nature as shore deposits, together with the presence of plant-remains in each, this absence of reptilia and mammalia in the Collyweston Slate seems more likely to be traceable to the absence of lagoon conditions than to any other probable source of difference.

It is well-known that the Yorkshire Oolites differ in many respects from those of the South-west of England. Among the rocks of that age in N.E. Yorkshire is one called the Millepore Bed, the fossils in which much resemble those common in the Inferior Oolite of the South-western district. Above this are some 80 to 100 feet of shales and sandstones, interstratified with at least eight distinct bands of coal. Mr. W. H. Hudleston† remarks that one of these bands is said never to exceed a thickness of 18 inches, though in general it is about 10 inches. Sir A. C. Ramsay states that the coal beds have not been formed of drifted vegetation, but that under each coal seam there is an underclay containing roots precisely like that underlying the coals of the Coal-Measures. We have thus in the Yorkshire Oolite eight beds of terrestrial origin in a total thickness of 80 to 100 feet of measures. Now, though this thickness is a mere trifle compared with that of the Coal-Measures, it is immensely greater than that of the Stonesfield Slate in which so many mammalian remains have been found, and which is on nearly the same geological horizon. But no mammalia have been discovered in these Yorkshire beds, in spite of their terrestrial origin and the abundance of Oolitic mammals elsewhere. Probably mammalia did not inhabit the coal-bearing swamps, and those living in drier parts and borne down the flooded streams to the sea were not retained in a lagoon. This case seems to me to

* 'Geology of England and Wales.'
† 'Proc. Geol. Assoc.' Vol. iii, p 310.

supply an excellent illustration of the danger of relying on negative evidence in the case of fossil remains, and of the immense influence of the conditions of their deposition on their preservation. How slight becomes the presumption against the existence of mammalia in Coal-Measure times derived from the non-appearance of their fossil remains, when we find that in Oolitic Coal-Measures—in a time and country in which they abounded—they have not been discovered.

In the beds of the Purbeck Series, which are sometimes classed as the topmost Oolites, sometimes united with the Wealden strata as the lowermost Cretaceous rocks, we again meet with mammalia. As in the Stonesfield Slate, they consist of small marsupials. The Purbeck Series are well known for their Dirt Beds, which are evidently old soils, in which the roots and the stems of trees are found in the positions in which they grew. Sir A. C. Ramsay says that the thickness of the whole of the Purbeck Beds is, in the Isle of that name, about 360 feet, and that according to the Geological Survey there are indications in them of four terrestrial surfaces, eleven sets of fresh-water beds, four brackish-water, and three marine. The mammalian remains, which are almost all simply lower jaws, have been found in a carbonaceous bed only a few inches thick, seen at Durlstone Bay. Mammalian lower jaws, as everybody knows, are the parts most speedily detached from floating carcasses of animals of that class. Mr. H. W. Bristow's table of Purbeck Beds shows that above the mammalian bed is a fresh-water bed, and below it "marly fresh-water beds;" while beneath these last are "soft cockle beds; chiefly marl, with gypsum and pseudomorphous crystals of rock-salt in places." This gypsum would seem to have been deposited in a salt lagoon which afterwards became freshened.

Both the small size and marsupial affinities of the fossil Oolitic mammalia of Britain have been much noted by geologists of eminence, who have also called attention to the fact that both the fauna and flora of the British Oolites are extremely like the recent animals and plants of Australia. After the spread of the marsupials, perhaps in Oolitic times, from the Eurasian continent to America by way of what are now Behring's Straits, and to Australia by way of the East India Islands, subsidences, with the consequent formation of sea-barriers, either prevented the admission, or largely reduced the number of the higher mammalia in Australia and

America. Hence the existence of what may be called from our point of view an Oolitic fauna and flora in Australia at the present day. Mr. A. R. Wallace ('Island Life') shows that the existence in central Australia of a broad belt of country from the Gulf of Carpentaria to the mouth of the Murray river, covered with rocks (according to our standard) of Cretaceous and Tertiary age, demonstrates that during those periods south-westerly Australia was separated from northern and eastern Australia by a broad sea, and that to this long isolation of south-western Australia is due the peculiar Australian flora of that region. Of course the same evidence which explains the special character of the land-plants of south-western Australia is equally good to show in what way the marsupial fauna of that country has been preserved. At an earlier period than that of the deposition of the Australian Cretaceous and Tertiary rocks, at a time when Australia had been more or less united to Asia by upheaval of the area occupied by the East India Islands, it became possessed of its peculiar fauna and flora, while subsequent subsidence, which has lasted almost to recent times, has preserved their peculiarities almost unmodified by the influence of organisms more recently developed, which flourish in the Eurasian continent.

It seems to me likely that the Oolitic marsupials of Britain were by no means so invariably small as the fossil remains yet found would incline us to believe. Marsupials, as we have seen, existed in Triassic times, and even if we suppose them to date from that period, a vast amount of time for modification elapsed between the deposition of the Trias and that of the Purbeck Beds; and when we learn from Dr. A. Geikie that the Stonesfield Slate has yielded the remains of four genera of marsupials, and that from the Purbeck Beds have been procured twenty species belonging to eleven genera, the smallness of the various forms seems to me more likely to have been due to local circumstances, such as the nature of the food obtainable and the habits of the creatures found, than to the non-existence of larger forms. In Australia at the present day the larger kangaroos are certainly not small animals, and in old river deposits of that country, which may correspond in Australia to the Miocene, Pliocene, and Pleistocene strata of Europe, are the bones of many extinct marsupials, some of very large size. Thus, one of the most abundant of these creatures is the *Diprotodon*, which was as large as a hippopotamus or rhinoceros, while the

skull of a certain extinct kangaroo is twice as long as that of the largest living animal of that kind. It seems to me, therefore, that, as important changes in the physical geography of Australasia have isolated in Australia a mammalian fauna of the same entirely marsupial type as that of the Oolitic period in Europe, the presumption is that in both districts there were large as well as small forms. The smaller mammals are necessarily both much more numerous and much more evenly diffused than the larger; for there are few spots in which small animals cannot obtain food and shelter, while large ones, though they may abound in places specially adapted to their habits and wants, are largely restricted to those places. Then, if any given number of the carcasses of mammalia, large and small, are floating down a river, they will tend to be deposited in different places according to their respective sizes. Some of the smaller forms may become entangled with the larger and sink with them, but as a general rule the small animals will float down the stream much farther than the larger ones. It may be remembered that Sir Samuel Baker enabled the parents of a drowned girl to discover her body by recognizing the fact that two bodies of about the same size and bulk, thrown in at the same place will tend to settle at the same spot.* He suggested that a log of heavy wood as near the girl's size as possible should be thrown into the rapids at the spot where she had disappeared. This was done, the log was found stationary about two miles lower down, in a back-water, and there also the girl's body was found. However, whether we suppose that the land adjacent to the spot at which our British Oolitic marsupials have been found was suited only to the habitation of small creatures, or that our deposits simply indicate that the smaller animals naturally drifted to the spots where they are now found, or are not quite satisfied with either explanation, enough has been said to show the little weight to be attached to merely negative evidence in this matter.

If we turn our attention for a moment to the nature and habits of existing marsupials we find that many of them are very small, are arboreal in their habits, live on insects, small birds, and fruits, and thus find excellent habitations in woods, on the banks of rivers, or even in mangrove swamps on the borders of the sea. For example, in America at the present day the Texas opossum is particularly fond of the black persimmon, which abounds on the

* 'Nile Tributaries of Abyssinia,' Chap. XI.

borders of the Rio Grande, while the crab-eating opossum is so called from the crab being apparently its favourite food. The Yapock, of Brazil, is a small creature, little more than a foot long, which lives on the banks of the rivers of Brazil and Guiana, and feeds upon fish, crustacea, and other aquatic animals. In Australia and Tasmania the phalangers are all small animals of arboreal habits, living on fruit, leaves, and small birds, while the bandicoot rats are small creatures, more insectivorous in their diet. Among the kangaroos there is a small tree kangaroo of arboreal habits, and a kangaroo of very large size, which lives in the woods which border most of the Australian streams. The other large kangaroos prefer open ground or hilly districts. The family to which the extinct genus *Diprotodon* belongs is now represented only by the wombat, a grass-eating animal, which burrows and lives among the hills.

If we are disposed to wonder why the largest of Australian marsupials have become extinct, I think we shall find the true explanation in the extraordinary droughts to which the country is liable. Even now, though great care has for some time been exercised in the storage of water, drought has been known to kill horses, cattle, and sheep by hundreds of thousands in a single year. The Australian explorer, Sturt, being brought to a standstill by the frightful heat and the want of water, dug out an underground chamber in which he and his men passed some terrible months. The wombat and many of the smaller marsupials are, as we have seen, of burrowing habits; but the gigantic *Diprotodon*, together with the huge extinct kangaroo and other large marsupials, more restricted to certain localities than smaller creatures, and without burrowing habits and capabilities, would naturally be among the first to fall victims to drought. This view receives confirmation from the fact that their remains are found in deposits of late Tertiary age, so that they must have become extinct during that comparatively recent period in which Australia became one great island, and droughts were rendered possible and inevitable. But a calamity of this kind can hardly have afflicted Western Europe in Oolitic and Cretaceous times.

The only indigenous mammal of Australia not marsupial is the carnivorous dingo, representing the ubiquitous dog family, the widely-distributed cats not being represented in that country. If we turn from Australia to Western Europe we find that the

mammals found in deposits of Lower Eocene age are almost entirely marsupial. And this is, at least, conclusive as to the abundance of marsupials in Europe at that time, however little it may decide as to the paucity of higher forms. Prof. W. Boyd Dawkins* tells us that among the carnivora of Western Europe in Upper Eocene times were creatures resembling wolves, foxes, wolverines, hyænas, and civets, "all with characters like the hyænodon, now only found among the marsupials." Among the mammals of Miocene age in Europe the opossum still lingered, though the remains of the higher mammalia have been discovered in much greater abundance. In Upper Miocene strata the cat family is represented by the great sabre-toothed lion (*Machairodus*), and in deposits of the same age have been discovered the rhinoceros, giraffe, deer, and antelope. No marsupials have been found in European beds of Pliocene age; and in the so-called "Forest Bed" of Norfolk, which dates from the time immediately preceding the Glacial Epoch, we have the sabre-toothed lion and the cave-bear, together with three distinct species of elephants, two of rhinoceroses, and many still existing mammals.

The "Forest Bed," though but a very few feet thick, is of the highest interest from the abundance of its mammalian and other remains. It may be seen at the base of the Norfolk cliffs between Happisburgh and Weybourn, as displayed on the admirable sheet of sections showing the coast between those places, drawn by Mr. Clement Reid and published by the Geological Survey. From Cromer westward it is seen to rest on the Chalk, and between Happisburgh and Cromer, Chalk is probably not far below the surface, though it becomes visible only for a short distance about Trimingham. At Happisburgh, Mr. Reid records that the Forest Bed is exposed at the base of the cliff after storms, and "generally consists of clay and loam with much lignite and occasional large mammalian bones. All the lignite and stools of trees appear to have been drifted." Near Bracton we learn that the Forest Bed is composed of blue clay with beds of lignite and gravel, the fossils being chiefly the bones and teeth of the elephant. At Paston the Forest Bed is very fossiliferous, large bones being particularly abundant. At Sidestrand its most abundant fossils are bones and teeth of two species of elephant, and the antlers and limb-bones of several species of deer; while between Overstrand and Cromer,

* 'Early Man in Britain.'

where the deposit is most fossiliferous, there have been found three species of elephant, and the remains of *Hippopotamus major*, *Rhinoceros etruscus*, *Equus caballus*, *Ursus spelæus*, and various kinds of deer, &c. It is also very full of fossil remains at East Runton, the bones of elephants, of *Trogontherium* (a kind of extinct beaver), and of deer having been discovered; while at Lower Sherringham the bones of elephants and deer are again recorded.

It is at once evident that the name "Forest Bed" is an unfortunate one to apply to strata in which the stools of the trees have all been drifted to the positions in which they now stand. But the remarkable thing among the mammalia, when contrasted with those from analogous formations of Oolitic age, is their great size. It is true that smaller forms are not entirely absent, but it is clear that in the Forest Bed the remains of large mammals are decidedly the most numerous. No doubt the mammalia of the Forest Bed period in Britain were, on the average, decidedly larger than those of our Oolitic age, even if we suppose marsupials as large as the *Diprotodon*, and the gigantic kangaroo, to have existed here in Oolitic times.* Still, whatever epoch we take, it seems unquestionable that the smaller mammalia must always have been vastly more numerous than the larger—in any considerable area there must always have been hundreds of creatures no bigger than a rabbit for one of the size of a buffalo or an elk, not to mention a rhinoceros or an elephant. The explanation seems to me to be that the drifted tree trunks and the carcasses of the large mammalia would tend to float away and to be stranded together in certain spots, while smaller creatures, similarly brought down the rivers to the shore, would, as a general rule, be carried farther on, though occasionally checked by obstacles in the shape of the larger animals and the drifted trees. Thus, in the Forest Bed, it appears to me that the geological record tends to give us an exaggerated notion of the average size of the mammalia of Britain, just as in the Oolites it probably gives an unfounded impression of their invariable smallness.

In 'Early Man in Britain,' Prof. W. Boyd Dawkins decides against the probability of the existence of man in the Miocene period on the ground that no living species of land mammal has

* Just as the mammalia of South Africa are on the average decidedly larger than those of South America, though the latter country is not destitute of large animals.

been met with in the Miocene fauna. He adds that "Man, the most highly specialized of all creatures, had no place in a fauna which is conspicuous by the absence of all the mammalia now associated with him." In treating of Pliocene times also he states that a certain argument against the probability of the existence of man in Italy during that epoch seems to him unanswerable. It is this. Of 21 species of fossil mammalia which inhabited Tuscany in the Pliocene age there is only one species now alive, and that it is highly improbable that man should be present in a fauna composed of so many extinct species, as "they belong to one stage of evolution, and man to another and a later stage."

While there can be no doubt that the circumstances on which Prof. Boyd Dawkins relies are by no means without a certain significance, a little consideration will show that they are by no means decisive; for the strong resemblance of the existing Australian mammals to those of the European Oolites, and the almost entire absence of the higher mammalia in that country, have shown how deeply the distribution of land-mammalia is affected by the existence or non-existence of land-passages between adjacent land-areas at certain periods. The nature of the mammals of Madagascar, as compared with those of South Africa, also testifies very strongly to the power of this influence. Yet in both these countries man was found as an indigenous mammal on their discovery, though in Australia the only other representative of the higher mammalia was the dingo, and in Madagascar the only other examples of the *Primates* were certain lemurs. In Africa, as everyone knows, man co-exists with monkeys, baboons, the chimpanzee, and the gorilla. Thus it is obvious that in Australia and Madagascar we should find the fossil remains of man in cave, river, or other deposits, in much lower mammalian society than that in which they might appear in Africa.

Now, as regards Tuscany, Sir A. C. Ramsay has pointed out* that the Alps must have been at the beginning of post-Miocene (or Pliocene) times, "prodigiously higher than they now are; and the amount of depression that the Mediterranean area underwent must have been commensurate, so to speak, with the great height to which the Alps, the Pyrenees, and other mountain ranges were upheaved in post-Miocene times." Thus the Pliocene period in Italy seems to have been one during which that country was

* 'Europe,' Chap. I.

peculiarly isolated, the Alps being more impassable than they now are, while the sea flowed over the plain of Lombardy and between Sicily and Africa; and, as we have seen, the mammals of an isolated area may differ in the most fundamental manner from those of neighbouring districts.

But primitive man, from a very early period, must have possessed considerably greater powers of crossing sea-barriers than the rest of the mammalia. If influenced by migratory instincts he might, by the aid of a rudely-constructed raft, take advantage of calm weather to cross straits which would be far beyond the natural swimming powers of the strongest and most active of other land-animals; and even where the watery channel might not prevent an animal from being now and then accidentally carried by favourable currents to the opposite shore, no permanent settlement there would be possible to stray individuals thus reaching it at considerable intervals of time. But men could construct a raft only by combining together to make one, and they would make one only for the purpose of settling in a new home across the water; and as the native Australian, who is now among the lowest of mankind, could hardly have travelled to his present home from the Eurasian continent without having crossed more than one strait, we may infer that European man, at a very early period of his existence, had a power of changing his environment far beyond that of the other land-mammals.

We are too much accustomed to look upon savages as men inferior to ourselves in everything of the slightest importance, and to forget that primitive man could not possibly have been gradually increasing his lead among animals during so many ages, except through the development of his powers of observation and reasoning. The main difference between the intellectual education of savages and that of more civilized men is due to the fact that savages have largely to struggle for their existence with other animals, while civilized men compete mainly with each other. But if savages are compared fairly with their more advanced brothers, the result will demonstrate that they possess special intellectual advantages as well as defects, their advantages being such as must be obvious to all members of this Association. Thus Mr. A. R. Wallace remarks —

"Savages make long journeys in many directions, and their whole faculties being directed to the subject, they gain a wide and

accurate knowledge of the topography, not only of their own district, but of all the regions round about. . . . His acute observation enables him (the savage) to detect the slightest undulations of the surface, the various changes of subsoil and alterations in the character of the vegetation that would be quite imperceptible to a stranger. His eye is always open to the direction in which he is going; the mossy side of trees, the presence of certain plants under the shade of rocks, the morning and evening flight of birds, are to him indications of direction almost as sure as the sun in the heavens."*

It is thus evident that the educated savage is decidedly proficient in that power of observing the phenomena of external nature in which the educated man of civilization is usually lamentably deficient, a deficiency the latter is now endeavouring to remedy by the study of natural science, and the formation of naturalists' field clubs.

It would seem that primitive man must have had, from a very early period, two great advantages over the other mammalia; a greater power of communicating his thoughts to his fellows, and the sole power of lighting a fire. Even if we suppose the language of the men whose implements we find in our river drifts to have been not more advanced than that of English children about two years old, the advantage may have been one of almost incalculable importance to them. And it seems to me that to the superiority of the intelligence of primitive man we indirectly owe the absence of his personal remains in the river drifts of the Thames and elsewhere, in which his implements are so abundant.

No doubt we may often find flint implements in gravel in which the bones of either man or of other animals must speedily have disappeared from the percolation of rain-water through the deposit. Yet there is nothing in the nature of man's bones to account for their non-appearance in river drifts, where those of deer, oxen, and other animals have been preserved, in periods during which man's implements show him to have existed. The true explanation seems to me to lie in the fact that man is not an animal whose habits and intelligence make it likely that his bones would appear in river drifts.

* 'The Limits of Natural Selection as applied to Man.' Livingstone makes similar remarks about the South African natives, 'Mission Trav.', Chap. I.

Even the largest creatures, such as elephants and rhinoceroses, are liable to be carried away on attempting to cross flooded rivers. Thus Sir Samuel Baker remarks in his journal ('Nile Trib.,' Ch. VIII): "A dead elephant floated down the river to-day; this is the second that has passed within the last few days." Other herbivorous creatures, such as oxen and deer, very frequently become the prey of the larger carnivora at drinking places by the waterside, the attack occasionally resulting in the drowning of both assailant and assailed. Hence the fact pointed out by the late Prof. John Morris, more than fifty years ago, that the remains of mammals in the river drifts of the Thames belong chiefly to the Ruminantia and the Carnivora, the former being abundant, and the latter sparingly distributed. Since the existence of the Carnivora (and especially of the Felidæ), these are the two orders we should expect to find especially well represented in a deposit containing Mammalia; and as only a percentage of the remains floating down a river would be preserved, those of genera forming one per cent. or less of the drifting carcasses would in all probability not be preserved at all.

But primitive men would have usually no difficulty in selecting sites for their dwelling-places, which would enable them to obtain water without danger from lurking Carnivora, while their keen powers of observation would enable them to avoid floods better than their fellow mammals. When man of the river-drift period fell a victim to some carnivorous animal, he would not generally perish by the waterside, but be pounced upon from some inland bush or crag, and devoured near the place of his capture, his remains being thus wholly lost to the geological record. Nowadays, except in certain islands, we obtain information about savages mainly when their more civilized competitors have deprived them of the best land and driven them to the worst. But in Palæolithic days, when men were few and far between, there was no pressure of population, and the best sites for temporary or permanent villages were all open to them. In every clime the Carnivora have been immensely more formidable to man as destroyers of his domestic animals than as slayers of himself. This is eminently the case in India at the present day, where, though they kill a very considerable number of cattle and other domestic creatures every year, the bites of snakes cause a loss of human life eight or nine times as great. Palæolithic man had

probably no domestic animals to attract Carnivora to his settlements.

My object in the foregoing remarks has been to remind you not merely of the fragmentary nature of the geological record as shown by the very large number of unconformities between different formations, but also to illustrate its extreme uncertainty as a guide to the nature of the terrestrial life of any given place and period. Mammalia, the most interesting and important of all animals, are of all the most certain to be represented by a selection, showing merely the forms whose habits made them especially liable to be buried in deposits of somewhat exceptional character, and which abounded near the place at which the deposit was formed. The uncertainty of mammalian evidence is well shown in Mr. Whitaker's recently published memoir on 'The Geology of London.' Readers of the very interesting chapter which consists of a 'Review of the Literature of the Thames Valley Drift,' will learn that while the two greatest stratigraphical authorities agree as to the formation of the valley and the respective ages of the beds, an eminent palæontologist had contested their views on the ground that they were diametrically opposed by the mammalian evidence, and would, "if proved to be true, overthrow the Palæontological value of the labours of all the Tertiary mammalogists." It is hardly necessary to point out that the stratigraphical position of beds is the only testimony furnishing absolute evidence of their age. Where stratigraphical evidence is wanting, that of fossils may give a presumption of more or less strength as to the affinities of a formation; but opposed to stratigraphical evidence its weight is nothing as regards the settlement of age, though it may be in the highest degree valuable and interesting in other respects. Speaking of these Thames Valley Drifts, Prof. Boyd Dawkins remarked in 1867,* that "the presence of *Elephas priscus* and *Rhinoceros megarhinus* indicates the affinity of the group to the Preglacial deposits of Norfolk, and to the foreign Pliocene strata. The tichorhine and leptorhine Rhinoceroses, on the other hand, point towards deposits of clearly-defined Postglacial age. . . . The beds under consideration are also as remarkable for the absence of some as for the presence of others of the Pleistocene mammals." In this case stratigraphical authority decidedly inclines to a belief in the (locally) postglacial origin of

* 'Q. J. G. S.,' Vol. xxiii.

the beds, while the palæontological evidence, as we have seen, is almost equally in favour of their preglacial, and of their postglacial age.

In conclusion, I would remark that evidence of ice-action in our later formations is not in itself necessarily sufficient to warrant us in dating them from the Glacial epoch. In the case of these Thames Valley Drifts, for example, some geologists see in the presence of large and but slightly worn blocks of stone in the terrace gravels but evidence of the action of river-ice; others look upon these blocks, and on slight surface contortions in these old river deposits, as establishing the rocks in which they appear to be of the Glacial Period. It seems to me that as river-ice is not only quite competent to produce these effects in Thames Valley Beds, but must often have produced them during the ages in which the river valley has been slowly assuming its present shape, glacial indications of this kind may possibly be of any postglacial period, and should not be referred to the Great Ice Age simply because they point to ice-action of some kind. We are now in the year of Jubilee as regards the recognition in England of ice action as a great geological agency, the famous papers of Agassiz and Buckland having been read before our Geological Society in the autumn of 1840. The geologist of to-day who reads an account of the discussion which took place after the reading of Buckland's paper* will find that at that time moraines, erratic blocks, boulder clay, etc., had been all lumped together as "diluvial detritus." He will note that Buckland, Agassiz, and Lyell were opposed by Murchison, Whewell, and Greenough, and that while the supporters of the glacial view had no conception of the former existence of a Great Ice Age in the northern hemisphere, their opponents relied on the wide extent of the sheets of "diluvial detritus" in low countries as showing how little the mere agency of glaciers could account for their existence.

I had thought of touching on certain matters connected with the Glacial Period, which, however, the time at my disposal will not allow me to discuss. I will therefore refrain from saying anything calculated to elicit that warmth of feeling which Glacial in common with Archæan questions invariably excite, and bring to an end these desultory remarks on the geological record.

* See 'Midland Naturalist,' Oct., 1883, where notes of the discussion taken by the late Dr. S. P. Woodward are given by Mr. H. B. Woodward.

On the Pleistocene (Non-Marine) Mollusca of the London District.

By B. B. Woodward, F.G.S., F.R.M.S., &c.

The object of the present communication, which from many causes has been long delayed, is to deal in as comprehensive a manner as may be with the non-marine * mollusca that occur in the Pleistocene (including in that term both the palæolithic and neolithic) deposits in the neighbourhood of London.

The area covered is practically that included in the Survey Memoir by Mr. Whitaker just published, and hence it might fairly be urged that the undertaking is premature, if not unnecessary, so soon after the issue of that admirable work. Justification is, however, sought in the fact that the scope of the Memoir did not permit of anything like an extended treatment of the subject, fossils, in a work mainly stratigraphical, being, of course, of subordinate consideration, whilst the unfortunate mollusca from these deposits come in for special condemnation on the grounds that there are amongst them no extinct species, and only three not now living in the area. The conclusion that the evidence afforded by the mollusca is of no value in any attempt to determine the relative ages of the several deposits is supported to some extent by the tabulated list of species there given ; but that list is a combination of the various records which have been published at different times and in various works, and no systematic checking of the determinations of the several observers is attempted, nor indeed is such practicable in a compilation of the sort.

Now, until comparatively quite lately any *Unio* that was not *U. littoralis* ranked as *U. pictorum ;* each *Clausilia* was *C. biplicata*, and every *Planorbis* with a keel, *P. carinatus ;* whilst a *Helix* that could not be referred to *H. hispida* or *H. nemoralis* seemed naturally to become *H. rufescens*. Nor is this much to be wondered at since when the older lists were compiled our British Mollusca were by no means so well known as they are at the present day, and the records were compiled by observers who were not always sufficiently acquainted with the living forms, and who certainly never

* This term is selected as being shorter than "Land and Fresh Water," and since it covers the inevitable introduction of brackish water forms like *Hydrobia*.

dreamt of applying to the microscope for aid in the determination of the fossil examples. It was enough that all were of "recent species."

The printer, too, is probably not without blame in some cases, especially in tabulated records, where many an asterisk under his fostering care has doubtless gone astray.

When, however, a careful scrutiny of these old lists is made, and comparison where possible instituted with the specimens themselves, it becomes manifest that if fairly studied and closely investigated, these despised molluscs are probably more likely to yield evidence concerning the history of the beds in which they occur than the mammals which are preferred before them; a result that might certainly be expected from the freshwater species, considering that they must more truly and more readily reflect any change in their natural environment than adventitious mammals can do.

Many obstacles have to be encountered in attempting such a task. Only too frequently a collection that would have been of the utmost value has been lost: for this the innate selfishness of the private collector, who insists on retaining his specimens until they get broken, lost, or dispersed, instead of placing them in some institution where others can study and derive advantage from them, is largely to blame. Where, however, the specimens are forthcoming, the difficulties in the way of a satisfactory determination of the species, despite the progress of conchology and the use of the microscope, are frequently serious if not insuperable; whilst the blunders that can be made even whilst doing one's utmost to avoid them, are both humiliating and exasperating.

In the present instance the method adopted when revising the old lists of collections that can no longer be traced, has been to omit all such names as it was felt sure or reasonably certain were due to error of observation, whilst giving on the authority of the recorder those species which could not justifiably be left out.

Besides, however, revising the collections and work of the past, new material has been laid under contribution, with the result that fresh points have come to light, and further species are added to the lists. That this has been possible is mainly due to the extremely kind assistance rendered on every hand. Dr. H. Woodward gave every facility for working at those specimens which are under his care as Keeper of the Geological Department of the

British Museum (Natural History); Mr. Franks permitted an inspection to be made of those shells which are preserved in his Department at Bloomsbury; Mr. Newton and Mr. Allen, of the Museum of Practical Geology, afforded every aid for the inspection of the examples there preserved; whilst the private collectors who freely allowed their treasures to be overhauled, and readily entrusted them for examination, are Mr. F. C. J. Spurrell, Mr. A. Belt, Mr. J. E. Greenhill, Mr. J. Allen Brown, Mr. C. J. A. Meÿer, Mr. R. Nuttall, Mr. T. Warburton, Mr. W. J. L. Abbott, Mr. G. F. Harris.

To all these friends the writer is greatly indebted, and takes this opportunity of cordially returning them his thanks, as also to Professor T. Rupert Jones for determining various species of *Cypris*, and to Mr. C. O. Waterhouse for naming the remains of beetles from the Blackfriars deposits; whilst to Mr. Worthington G. Smith, Mr. E. T. Newton, Mr. E. A. Smith, Rev. E. S. Dewick, and Mr. W. Rupert Jones, he is under great obligation for assistance and advice.

For permission, in all cases most readily granted, to reprint the illustrations of the various sections alluded to, especial thanks are due to the authors of the papers—Prof. Prestwich, Prof. Boyd Dawkins, and Mr. W. T. Blanford; to the Council of the Geological Society, and to the Controller of Her Majesty's Stationery Office; whilst to the editor of the 'Geological Magazine' (Dr. H. Woodward), to Mr. Worthington G. Smith, and to the Essex Field Club the Association is indebted for the loan of the blocks themselves.

The final results as regards the determination of the molluscan species present in the Thames Valley Post-Glacial deposits will be found summed up in the table at the end. For purposes of comparison it has been thought advisable to give in the first column a complete list of the mollusca known in the British Isles (in this the names of the extinct forms have been inserted in their proper position in ordinary type), then in the second column those are indicated which are living at the present day in the area drained by the Thames and its tributaries, and might therefore be expected to be found in the deposits under consideration; whilst the forms which actually do so occur in beds even the most recent are marked in the subsequent columns under the names of the several localities. These are arranged to a certain extent in

what appears to be chronological order, that is to say—Recent, Alluvial (Neolithic), between the several localities for which no difference in age is distinguishable, and River Drift (Palæolithic), in which it is thought some slight difference in age is perceptible.*

BIBLIOGRAPHY.

The bibliography of the subject is not extensive, as the subjoined list (v. pp. 386-7) shows; for it was not until 1813 that such trivial and unimportant things as shells occurring in the brick-earths of the Thames Valley were noted, and then the sole allusion to them that Mr. Trimmer makes is confined to the observation that "snail-shells and the shells of river-fish" were found in company with various bones of Mammals at Brentford. Nor is there more than a mention of the occurrence of shells in the succeeding paper by Professor Morris in 1836, and it was not till 1838 that lists of the species from the various localities then known were published in tabular form by the latter geologist.

For clearness sake, the full titles and references to the several papers are given in the list, and no author having, fortunately, written twice in the same year, subsequent references to these papers will be, for brevity's sake, made by date only, placed after the authors' names.

NOTES ON THE LOCALITIES.

RECENT AND ALLUVIAL (NEOLITHIC).

Erith Marshes.—These specimens were obtained by Mr. F. C. J. Spurrell from the ditches close down by the river. Two species amongst them in the list are found in no older soil—*Helix cantiana* and *Sphærium lacustre*.

Thames Mud, Westminster.— The specimens here recorded were obtained from the section† exposed in 1876, when the foundations of what was to have been the great English Opera House, but is now the new Scotland Yard, were being laid.

* The terms "Alluvial" and "River Drift" adopted by Mr. Whitaker are here followed, though "Neolithic" and "Palæolithic" might possibly have been better, seeing that Alluvial is river drift and River Drift is alluvial. The decision of the Geological Congress Commissioners to adopt "Recent" and "Pleistocene" for these two is still less happy as regards the former, since we do not live in neolithic times, and "recent" has too long been in use to express living as opposed to "fossil" for palæontologists to readily speak of "Recent" fossils.

† 'Proc. West London Scient. Assoc.,' Vol. i, p. 78.

One species, *Planorbis carinatus*, from this deposit is worthy of note, inasmuch as many of the specimens, and they are abundant, were devoid of the prominent keel which is so striking a feature in this species. Its absence gives so peculiar a look to the gathering as at first sight to suggest a new species.

Moorfields.—Some years ago Mr. T. Warburton obtained from an excavation made for building purposes, alongside St. Mary's R.C. Chapel, Moorfields, at a depth of 20ft., a series of shells, which he now kindly allows to be recorded.

Excluding such accidental occurrences as *Mytilus edulis*, *Cardium edule*, and *Helix aspersa*, with the periostracum still adhering, that must manifestly belong to the London kitchen-midden or dust-bin period, the shells are all of fresh-water species.

The excavation would seem to have been made in a portion of the bed of the old Wall Brook, whose name still survives in that of a street within the City precincts. It may even have touched on the deposits of the old marsh that once existed close to the spot.* Judging from the size to which many of the examples attain, the living must have been a fat one indeed. One specimen of *Limnæa stagnalis* attains an altitude of 47 mm., with max. and min. diam. of 28 and 20 mm.

Candona candida has been determined by Professor T. Rupert Jones from this spot.

Staines.—From Mr. J. Allen Brown comes the record of a deposit rich in molluscan remains, which is higher up the river valley than any of those here to be treated of. He writes of it as follows :—

"The section at Staines, where the deposit occurs in which I found the mollusca, is on the left bank of the Thames, fully a mile west of Staines, on the tow-path towards Old Windsor. The present channel of the river has been eroded in its old bed, which was then at a higher level than the present stream. The lower part of the bank is there a mass of shells, intermixed with small fragments of carbonized wood and small nodules of race. The bed is surmounted by brick-earth, three or four feet in thickness. The deposit is so thick in organic remains that I intend at the earliest opportunity to again investigate it, and at a future time to lay a fuller account of it before the Geologists' Association."

Some of the *Pisidia* have their valves still united. The most

* See Loftie's 'London,' Vol. i, opening chapters.

noteworthy shell is an extremely fine specimen of *Succinea elegans*, which, although wanting the top of the spire, measures 24 mm. in height, and when perfect must have been as much as 26 mm., or just over 1 in. in height, whereas 15 mm. is the average size of recent specimens.

Thames Ditton.—A section here in 1867 (Fig. 1) laid bare an alluvial bed with shells (Whitaker, 1889, p. 425), but no record appears to have been kept of them.

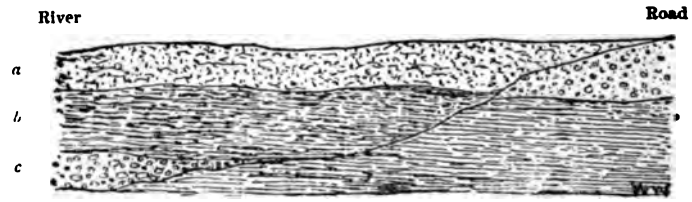


FIG. 1.—SECTION AT PART OF THE FILTER-BEDS OF THE LAMBETH WATERWORKS, THAMES DITTON, 1867.

[Reprinted from 'Geol. Surv. Mem.' London, Vol. i, by kind permission of the Controller of Her Majesty's Stationery Office.]

a Made ground.
b Alluvial clay and sand, with shells.
c Gravel at two levels.
d Grey London Clay.

Kew.—The late Mr. T. Belt, so widely known as the author of 'The Naturalist in Nicaragua,' paid very considerable attention to the geology of his own neighbourhood. In addition to his published writings on this subject, he left behind him many unpublished notes, and through the kindness of his son, Mr. A. Belt, the following observation is extracted from his MSS. :—

"January 18th, 1877.—At Kew, by the river-side, in digging for foundation of large boat-house, they have sunk through about 6ft. feet of alluvium, consisting of a loamy clay, with many shells of *Helix*, *Zua*, and *Limnæa*. In the same place saw gravel taken out of the river, in which were many shells of *Unio*. The first-mentioned appears to be what forms in the marshes bordering the river, and only occasionally over-flowed by it, and in both we see that shells are plentiful."

The shells, which are still preserved, are recorded in the table, and include a keel-less example of *Planorbis carinatus*, similar to those mentioned from the Thames mud at Westminster.

Brentford.—Mr. T. Belt has also recorded (1878, p. 335) the

occurrence of the following shells in "laminated sandy clay or silt" near Brentford (Fig. 2) :—*Helix pulchella*, *H. caperata*, and *Cochlicopa* (*Zua*) *lubrica*.

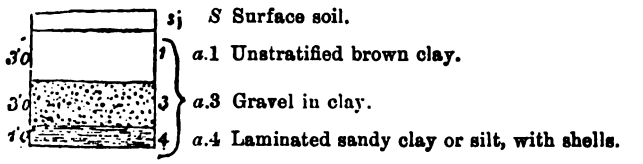


FIG. 2.—SECTION 30 YARDS SOUTH OF FLORA VILLAS.
[Near Avenue Road, Windmill Lane—After T. Belt, 'Quart. Journ. Sci.,' xv.]

Fulham.—At the eastern end of Bettridge Road, Fulham, a small pocket of loamy silt full of shells was found. From specimens kindly forwarded by Mr. F. Chapman the following species were obtained* :—

Limnæa peregra.	*Valvata piscinalis.*
Planorbis albus.	*Neritina fluviatilis.*
—— *nautileus.*	*Sphærium corneum.*
—— *carinatus.*	*Pisidium amnicum.*
Bythinia tentaculata.	—— *fontinale.*
—— *leachii.*	

The number being so small, and all the names occurring in the Westminster list, no note is taken of them in the table. Amongst them there is a remarkable example of *Valvata piscinalis*, extremely turreted and having five full whorls, or at least half a whorl more than is usual, even in fine examples.

Westminster.—Below the Thames mud in the section already mentioned, and separated from it by a layer of peat, was some fifteen feet of sand full of shells.†

With these may be taken a quantity of shells, presented to the British Museum by Mr. W. Davies, the label with which reads :—

"Associated with vertebrata in river gravel below level of low-water mark in digging foundation of the river wall at the south-west end of the terrace of the Houses of Parliament. July, 1875."

Both in position and in the nature and state of preservation the shells from these two localities so closely agree that there can be no doubt as to the propriety of thus putting them together.

* Some examples are now in the Natural History Museum.

† Between this last and the London Clay a bed of coarse gravel intervened, probably belonging to the River Drift.

Whitefriars.—In John Carpenter Street, near the Guild Hall School of Music, Mr. W. J. Lewis Abbott has recently observed in a series of sections made in connection with sewage works, and at a depth of from ten to fifteen feet from the present surface, a sandy layer containing shells. This rested on peat, which again overlay the river drift with palæolithic implements. All these shells are fresh-water forms, and the deposit most probably accumulated at the mouth of the old Fleet Ditch in the early days of the city's existence.

That a valve of *Dreissensia polymorpha* should be amongst those found is certainly remarkable, since its occurrence was not noted in this country till about 1824.

Blackfriars.—On the opposite side of the river, at the time of the construction of the Charing Cross railway, a series of excavations were made in Blackfriars revealing a fresh-water deposit containing shells, etc. This was described by the late Mr. C. Evans in the 'Proceedings,' and a list of the shells, as determined by Mr. C. J. A. Meÿer, given (1863, p. 266). Mr. Evans' specimens are now in the writer's possession, whilst Mr. Meÿer most obligingly forwarded his for inspection, thus enabling a complete investigation to be made.*

The following changes have had to be made in the published list:

Helix hispida?	is now	*H. concinna.*
Succinea pfeifferi	,, ,,	*S. elegans.*
Planorbis carinatus	,, ,,	*P. marginatus.*
,, *lacustris*	,, ,,	*P. lineatus.*
Pupa [sp.]	,, ,,	*Vertigo antivertigo.*

Clausilia was given without specific determination, but an apical fragment was found which cannot be distinguished from the similar portion of *C. biplicata.*

The following are added to the list from Mr. Meÿer's collection:

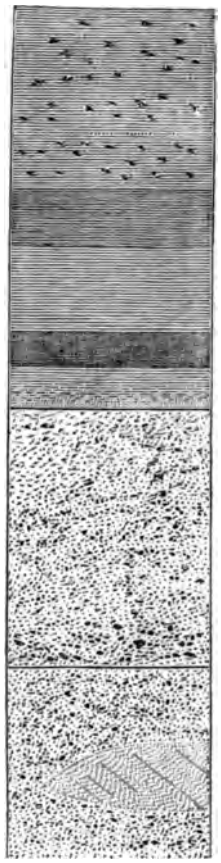
Hyalinia nitidula.
,, *nitida*
Helix arbustorum.
Pisidium pusillum.
,, *fontinale.*

Professor Rupert Jones has identified *Candona* (*Herpetocypris*) *reptans* from this deposit, whilst the wing cases of beetles have been referred by Mr. Waterhouse to *Pterostichus vulgaris*, *P. lepidus* (*?*), and *Donacia lemnæ.*

* A series of these shells is now in the Natural History Museum.

Greyfriars.—In the collection of Mr. J. Allen Brown there is a right valve of *Unio tumidus*, marked as having been "found in Little Britain, full 20ft. below the surface." Beyond the loss of the periostracum the shell is hardly altered at all.

The Docks.—Mr. W. T. Blanford described, in 1854, a section (Fig. 3) in the West India Docks, and, in a note, alluded also to



	ft.	in.
a & *b* Clay, gravel, soil, &c. ("made earth")	11	11
c Brown and blue clays with a few freshwater shells	4	6
d Peat, with stems of trees and shells in one place	1	8
e Clay of variable character passing downwards into sand	2	0
f Sand and gravel; the latter very ferruginous at the top. The sand prevailing in the upper part. The gravel much coarser towards the bottom...	13	6
g Pebbles and rolled clay, with broken shells; also (*g**) patches of green sand with plant and insect remains.		

FIG. 3.—SECTION EXHIBITED BY EXCAVATIONS IN THE WEST INDIA DOCKS.

[Reprinted by kind permission of the author, and of the Council of the Geol. Soc. from their 'Quart. Journ.,' Vol. x.]

another section in the Victoria Docks. From both places he obtained shells which are still preserved in the Geological Society's Museum. Ten species, besides a fragment of *Unio* (probably *U.*

tumidus), are cited by him from the former locality. Three of these are missing—*Succinea putris*, *Ancylus fluviatilis*, and *Limnæa peregra*. *Sphærium corneum*, which had been overlooked, can now be added. Broken specimens of *Cyrenæ*, that had, of course, been derived from the lower Tertiaries, were also found.

From the Victoria Docks Mr. Blanford cited (p. 435) four species which he had not noticed at Tilbury. An examination of the specimens, still in their original boxes, showed that with *Helix rufescens* were also *H. rotundata*, *H. concinna*, and *Hyalinia nitida*. The specimens marked "*Limnæus auricularis*" were inflated varieties of *Limnæa peregra*; and the "*Planorbis nitidus*" was *P. marginatus*.

In addition to *Neritina fluviatilis*, the following (which were not specially noted by Mr. Blanford, since they also were in his West India Dock section) were present from that locality:—

Helix nemoralis.	*Bythinia tentaculata.*
Succinea elegans.	*Valvata piscinalis.*
Ancylus fluviatilis.	*Pisidium amnicum.*
Limnæa palustris.	„ *fontinale.*

With these the shells obtained by Mr. F. C. J. Spurrell (1889), from the Albert Dock (Fig. 4), are united in the table. Since his list was published *Limnæa palustris* has been found amongst the material, and added to the record.



FIG. 4.—SECTION IN THE MIDDLE OF THE ROYAL ALBERT DOCK, A LITTLE WEST OF HAM MANOR WAY.

[Reprinted from 'Geol. Surv. Mem.,' London, Vol. i, by kind permission of the Controller of Her Majesty's Stationery Office.]

About 60 yards long and about 15 feet high.

1 Clay 2 Peat	Alluvium.
3 Sand, 7 feet 4 Gravel, 3 feet shown	River Drift.

Crossness and Tilbury (Sections, Figs. 6, 7, 8), recently described in these 'Proceedings' by Mr. Spurrell (1889), call for no further remark beyond recording the few changes which a further inspection of the material has rendered necessary.*

* A series of the specimens has now been placed in the Natural History Museum.

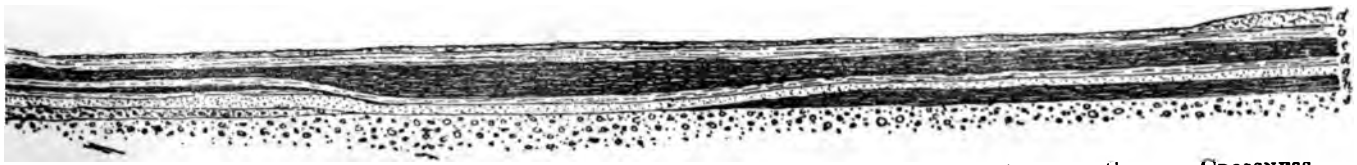


FIG. 5.—SECTION NEARLY ALONG THE WESTERN SIDE OF THE RESERVOIR, SOUTHERN OUTFALL SEWER, CROSSNESS.

[Reprinted from 'Geol. Surv. Mem.,' London, Vol. i, by kind permission of the Controller of Her Majesty's Stationery Office.]

Scale (vertical and horizontal) 88 ft. = 1 in.

a Soil
b Brown silty clay
c Peat
d Blue clay
e Peat } Alluvium.
f Blue clay
g Soft sand and clay
h Soft peat and clay

i Fine sandy gravel } River Drift.
j Grey subangular flint-gravel

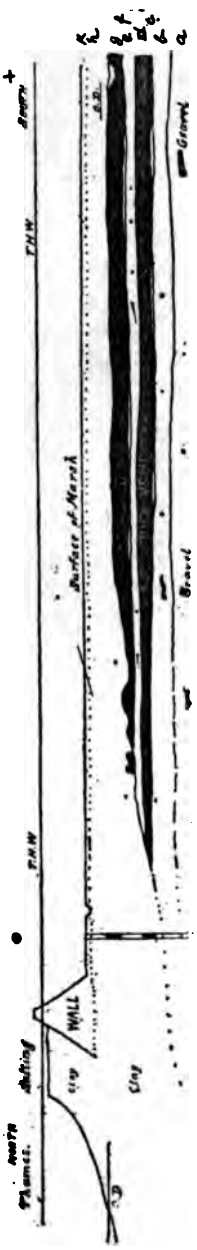


FIG. 6.—SECTION AT CROSSNESS.

[' Proc. Geol. Assoc.,' xi, 217.]

a Gravel } River drift.
b Sand }
c Sandy clay full of freshwater shells }
d Peat, lower
e Tidal blue clay
f Beds of sand and shells as above } Alluvium.
g Peat, upper
h Tidal clay
k Arable soil

o Boring to the west, showing the same beds.
The black marks represent drift wood.

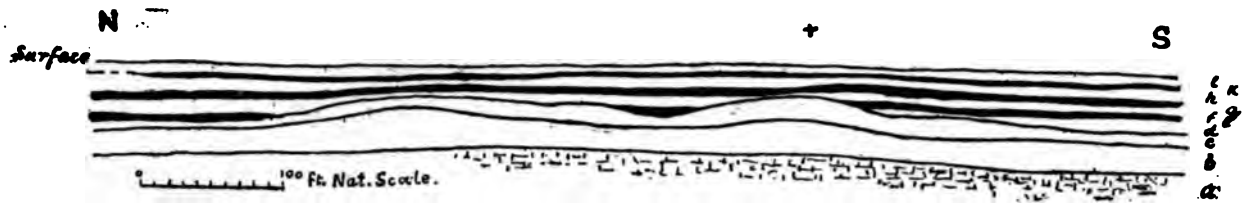


FIG. 7.—SECTION IN TILBURY DOCK.

['Proc. Geol. Assoc.,' xi, 215.]

a Chalk.
b Gravel } River Drift.
c Sand }

d f h l Tidal clay
e g k Peat (with mud and sand containing freshwater and land shells } Alluvial.

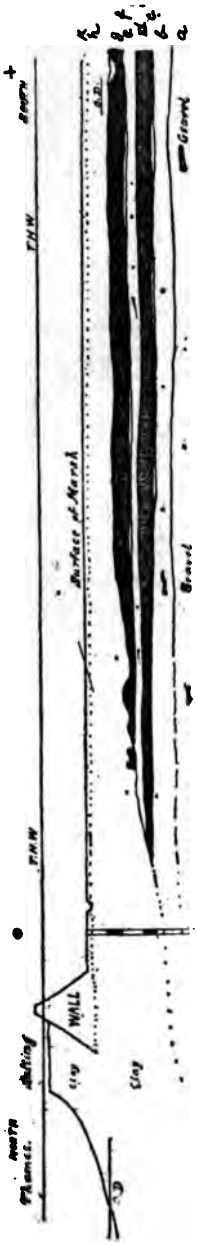


FIG. 6.—SECTION AT CROSSNESS.

['Proc. Geol. Assoc.,' xi, 217.]

a Gravel } River drift.
b Sand }
c Sandy clay full of freshwater shells }
d Peat, lower }
e Tidal blue clay } Alluvium.
f Beds of sand and shells as above }
g Peat, upper }
h Tidal clay }
k Arable soil }

o Boring to the west, showing the same beds.
The black marks represent drift wood.



FIG. 7.—SECTION IN TILBURY DOCK.

['Proc. Geol. Assoc.,' xi, 215.]

a Chalk.
b Gravel } River Drift.
c Sand

d f h l Tidal clay
e g k Peat (with mud and sand containing freshwater and land shells } Alluvial.

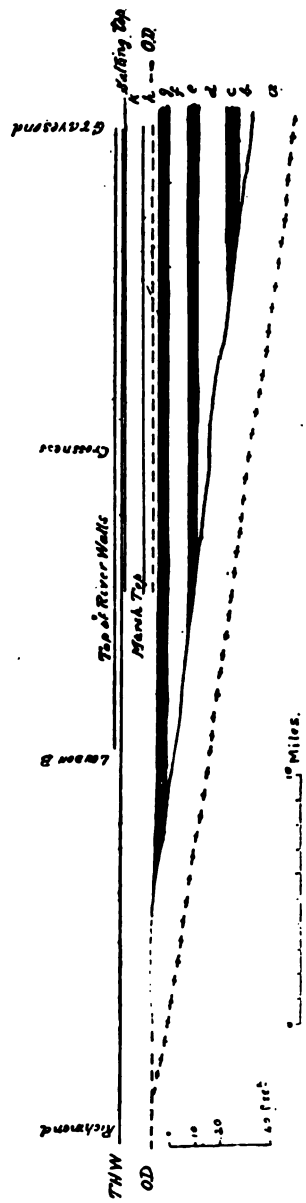


FIG 8.—DIAGRAM-SECTION ALONG THE COURSE OF THE THAMES.

['Proc. Geol. Assoc.,' xi, 211.]

a Layer of old river sands and gravels [River Drift.]
b Tidal clay with sand.
c Peat.
d Tidal clay.
e Peat.
f Tidal clay.
g Peat on which Roman remains lie.
h Surface clay.
k Clay now accumulating to form saltings.

To the Crossness list are now added *Anodonta cygnæa* and *Helix pygmæa*. *Pupa umbilicata* should have been *P. muscorum*, and *H. concinna* is removed, the specimen seeming on a closer inspection to be rather *H. rufescens*. Professor T. Rupert Jones has recognized *Cytheridea torosa* var. *teres* from this locality, and *Candona candida* from Tilbury.

The only alteration in the Tilbury mollusca is the removal of *Planorbis marginatus* from the list, into which it crept by accident.

Lea Valley.—On either side of the Lea, between Walthamstow and Clapton, and close down to the stream, there is a series of peaty and marly alluvial deposits, full of molluscan and vertebrate remains.

A list of the shells from the former locality was given by Dr. Woodward (1869, p. 387), who described the sections (Figs. 9, 10, 11) seen there.

FIGS. 9-11.—SECTIONS EXPOSED DURING THE CONSTRUCTION OF THE RESERVOIRS OF THE EAST LONDON WATERWORKS COMPANY, AT WALTHAMSTOW.

[Reprinted by kind permission from 'Trans. Essex Field Club,' Vol. iii].

Bed No. 1. Surface soil, 12 inches

„ „ 2. Clayey loam, 18 inches

„ „ 3. White shell-marl, 10 inches.

„ „ 4. White-coated subangular gravel encrusted with lime from super-imposed shell-marl, 18 inches.

„ „ 5. Rounded and subangular gravel* stained with oxide of iron (actual depth not ascertained.)

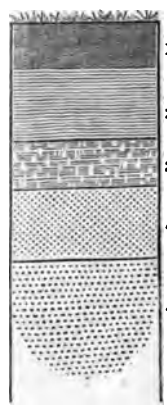


FIG. 9.—Section at the south-east corner of the Eastern Reservoir.

* This gravel (No. 5), which forms the floor of the reservoir, is of very considerable thickness. At one spot, where pumping for "puddling" had been going on, a hole more than ten feet in depth from the surface of the gravel bed still showed the same gravel, with abundance of water.

Bed No. 1. Vegetable mould, 12 inches.

„ „ 2. Stiff brown clay, 24 inches.

„ „ 3. Shell-marl and marly clay, 12 to 36 inches.

„ „ 4. Stiff dark clay, with wood, 18 inches.

„ „ 5. Peat, 24 inches, lying on.

„ „ 6. Thin band of black gravel, stained by overlying peat, 3 inches.

„ „ 7. Clean red gravel, corresponding with Bed No. 5 in Fig. 1, forming floor of reservoir.

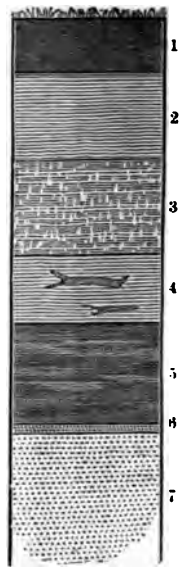


FIG. 10.—Section at south-west corner of Reservoir.

Bed No. 1. Surface soil, 18 inches.

„ „ 2. Stiff clayey loam, 18 inches.

„ „ 3. Very compact black peat, 3 feet.

„ „ 4. Shell-marl, 12 inches.

„ „ 5. White-coated subangular gravel, 12 inches.

„ „ 6. Clean red gravel, forming floor of reservoir, and equivalent to Bed No. 5 in Fig. 1, and to Bed No. 7 in Fig. 2.

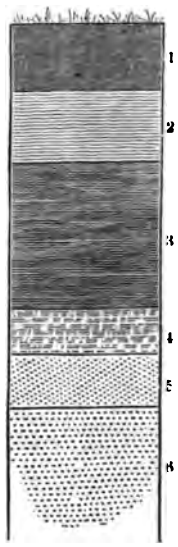


FIG. 11.—Section in the Eastern Reservoir, and near the Embankment between the Eastern and Western Reservoirs.

The material is at the Natural History Museum, and having been carefully gone over the following changes are made:—*Helix hortensis*, *H. ericetorum* and *H. caperata* are removed from the list, not having been found; *Clausilia bidens* has been altered to *C. laminata*, *Planorbis carinatus* to *P. marginatus*, and *Bythinia ventricosa* to *B. leachii*. Seventeen new names have been added:—

Hyalinia radiatula.
„ *crystallina.*
„ *nitida.*
Helix rotundata.
„ *lamellata.*
„ *pulchella.*
„ *concinna.*
Pupa muscorum.
Vertigo antivertigo.
„ *pygmæa.*
Planorbis albus.
„ *nautileus.*
„ *spirorbis.*
„ *contortus.*
Physa fontinalis.
Valvata cristata.
Pisidium fontinale.

Of these *Helix lamellata* is the most noteworthy, the species not having previously been recorded from any Pleistocene deposit so far south. It occurs at Copford and near Chelmsford, in beds of about the same age, and at Barnwell in the older River Drift deposits; but at the present day its southern limit is Yorkshire.*

The beds on the other, or Clapton, side of the stream have been worked out and described by Mr. J. E. Greenhill, whose specimens† have by his kindness been gone over, with the result that his published list (1883, pp. 23 and 24—sep. paper, pp. 3-4) has to be corrected in the following particulars:—

Helix aculeata, *H. hortensis*, and *H. ericetorum*, *Limnæa glabra*, *Pupa umbilicata*, and *Zonites radiatula* are removed from the list, the specimens being non-existent, whilst the names, mostly introduced from older lists relating to the River Drift beds, have been decorated by the printer with the star in the wrong column. One species is retained on the authority of Mr. Greenhill, and so marked in the table.

Clausilia biplicata has been altered to *C. laminata*, and *Succinea gracilis* to its synonym *S. elegans*. Thirteen species are added to the record:—

* It has just been re-discovered in Staffordshire, 'Journ. Conch. Soc.,' vi. (1890), p. 254.

† Some are now in the Natural History Museum.

Hyalinia nitidula.
„ *fulva.*
Helix rotundata.
„ *concinna.*
„ *rufescens.*
„ *lapicida.*
Vertigo pygmæa.
Ancylus lacustris.
Planorbis albus.
„ *contortus.*
Valvata cristata.
Pisidium pusillum.
„ *fontinale.*

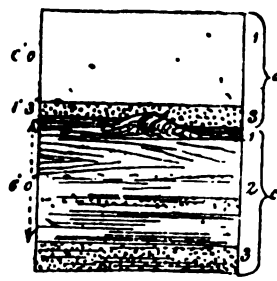
Two examples of *Valvata piscinalis* were very fine, measuring 7 mm. in height by the same in max. diam.

The state of preservation of the shells in the Alluvial beds is pretty much the same in most instances. The periostracum is frequently still preserved, especially in the bivalves, but as a rule all animal matter has been removed, and the shells are not uncommonly stained a bluish black, especially where peaty matter is present. Occasionally, as at Westminster, some are encrusted with tufa, which seems especially to affect *Limnæa peregra*, *Unio tumidus*, and *Neritina*. This last always retains its coloration.

The specimens from Staines, Brentford, and Kew are by exception remarkably white, and free from staining of all sort.

RIVER DRIFT (PALÆOLITHIC).

Brentford.—This, as already mentioned, is the locality where shells are first named as occurring in the London Pleistocenes (Trimmer, 1813—See Belts' sections, figs. 12, 13), but the first list of those found was not published till 1850 by Professor Morris, who remarks (1850, p. 203, section fig. 14):—"The

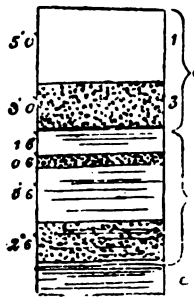


a 1. Brick-clay.
a 3. Gravel in sandy-clay, with some dark brown sand at base.
c 1. Curled yellow sand, with fragments of freshwater shells.
c 2. Sand and sandy loam, with thin layers of clay, some small angular gravel, and minute fragments of shells.
c 3. Sandy subangular gravel.

FIG. 12.—SECTION N.W. CORNER OF MR. TRIMMER'S OLD BRICKFIELD.

[After T. Belt, 'Quart. Journ. Sci.,' xv.]

shells were but few in number in this locality, as compared with the more eastward deposits in the Thames Valley [*i.e.*, *Grays*,



a 1. Brick-clay removed by Mr. Trimmer.

a 3. Gravel in clay.

c Layer of sand at top; then 6in. of gravel containing broken valve of *Unio;* then sand and gravel.

e Yellow sand. *Unio* and *Cyclas* [= *Sphærium*] *rivicola* common.

FIG. 13.—SECTION EAST END OF MR. TRIMMER'S OLD BRICKFIELD.

[After T. Belt, 'Quart. Journ. Sci.,' xv.]

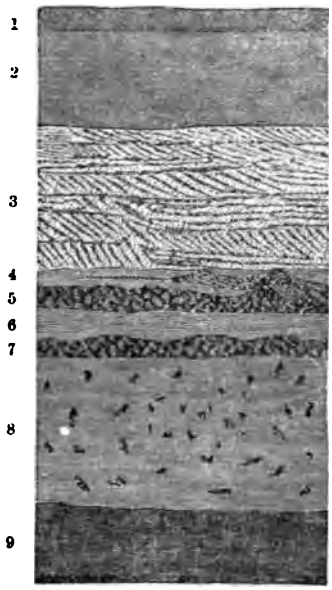


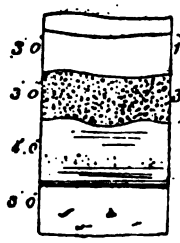
FIG. 14.—SECTION OF RAILWAY-CUTTING AT BRENTFORD.

[Reprinted by kind permission of the Council from 'Quart. Journ. Geol. Soc.,' Vol. vi.]

1. Vegetable mould; 1 foot.
2. Brickearth, a fine brownish loam; 4 feet.
3. Fine sand, mostly stratified and obliquely laminated, with occasional wavy and irregular veins of small gravel; 6 feet.
4. Sand, with light-coloured clay and irregular gravel, containing bones; 6 to 8 inches.
5. Ferruginous gravel and sand, with patches of clay; 1 foot.
6. Clayey sand and sandy gravel, with occasional large flintstones, partly ferruginous at the upper part, containing bones and shells; 1 to 2 feet.
7. Ferruginous sand and gravel; about 6 inches.
8. Light clayey sand and ferruginous gravel, with boulders of quartz, granite, rock with ammonites, etc., also bones, etc., of ox, deer, etc.; 6 to 7 feet.
9. London Clay.

etc.]. . . . Not even fragments of *Cyrena trigonula* [= *Corbicula fluminalis*] and *Unio littoralis* were observed."

The next and fuller list was that issued by Mr. T. Belt (1878, p. 335) on the determination of Dr. J. Gwyn Jeffreys. His specimens were obtained at a spot, close to the former site, "opposite Flora Villas" (Fig. 15), which seem to be near to Avenue Road, Windmill Lane. By digging down another eighteen inches in the floor of the



s Surface soil.
a 1 Brown clay.
a 3 Gravel in clay.
c Coarse yellow sand, with a band of subangular gravel; a few broken shells in lower part.
f Sharp yellow sand, with mammalian remains and freshwater shells, common. Base not reached.

FIG. 15.—SECTION OPPOSITE FLORA VILLAS.

[After T. Belt, 'Quart. Journ. Sci.,' xv.]

pit, and thus reaching a lower stratum than had been investigated before, Mr. Belt succeeded in procuring "a great number of shells, amongst which were specimens of *Unio littoralis* and *U. pictorum* [or, rather, *U. tumidus*], with the two valves united. Many of the small Cyclades also were perfect. . . . This sand is full of shells, amongst which the little *Hydrobia marginata* [Fig. 37, No. 8] is abundant." He further remarks that "the shells . . . were soft, and those of the Unios split up as they dried. . . . *Hydrobia marginata* was the most abundant." Through the kindness of Mr. A. Belt, in whose possession they are,* these shells have been examined, with the result that it was shown necessary to remove *Unio pictorum* from the list, substituting in its place *U. tumidus*, and to add *Helix concinna*, *H. hispida*, *H. caperata*, and *Sphærium rivicola*.

Certain other species are included in the table from Professor Morris and Dr. Jeffreys' lists, since though not found in the series examined there is nothing improbable in their occurrence. *Limnæa auricularia* and *L. stagnalis*, however, though cited by Morris, are left out, since, judging from other instances, these were probably errors for *L. peregra* and *L. palustris*.

Mr. J. Allen Brown has obtained specimens from almost pre-

* A set is now in the Natural History Museum.

cisely the same spot as Mr. Belt, and these were most kindly submitted for inspection. They confirmed the determinations, while adding nothing new, for the two additional names (*Paludina*, sp., and *Helix rotundata*), cited in Mr. Brown's published list (1887, p. 113) were unrepresented in the collection, and have consequently been omitted.

The examples of *Pisidium amnicum* from this locality are very fine, and remarkable for being much more inflated at the umbones than is the typical form, whilst at the same time they appear heavier and more solid.

North-East London.—Of all the localities to be dealt with this district seems to have offered more difficulties in its solution than any other, owing to various causes that need not now be considered.

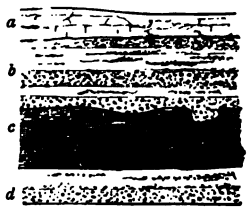


FIG. 16.—SECTION IN GRAVEL-PIT, SHACKLEWELL LANE, WEST HACKNEY.

[Reprinted by kind permission of the author and of the Council of the Geol. Soc. from the 'Quart. Journ.,' Vol. xi.]

a Brick-earth. 2 to 3 feet.

b Ochreous flint-gravel, with subordinate irregular layers of ochreous and yellow sand. 6 feet.

c Dark-grey sandy clay, full of vegetable matter, with some bones and numerous shells. 2½ feet.

d Light-yellow sands and ferruginous gravel. (Depth not proved.)

So far as the shells are concerned, its history commences with Mr. Prestwich's paper in 1855, when the first list was published, the species being determined by Mr. Pickering. The section described was in Hindle's gravel-pit, Shacklewell Lane (Fig. 16), and close to the course of the Hackney Brook. The shells occurred in a layer of sandy clay, below gravel and brick-earth, at a depth of from 8ft. to 10ft. from the surface.

Mr. Pickering's list cites 23 species, amongst which *Corbicula fluminalis* is not to be found; but eight valves were presented to this Association by him in December, 1860, which are labelled

'Cyrena consobrina—West Hackney gravel pits. These shells are from a bed of sand and gravel below the beds described by Mr.

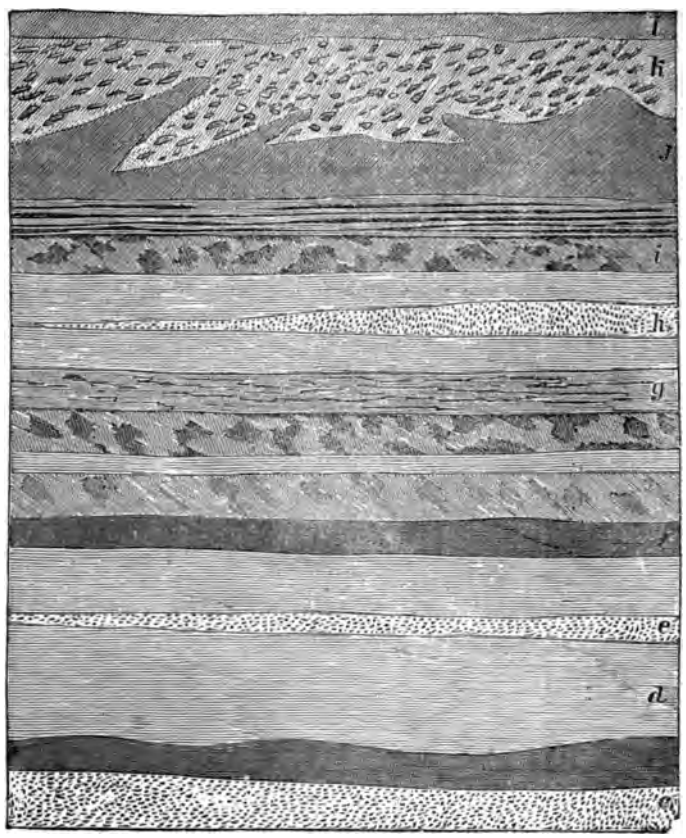


FIG. 17.—SECTION IN STOKE NEWINGTON PIT.

[Reprinted by kind permission of the Council from 'Quart. Journ. Geol. Soc.,' Vol. xxv.]

l [Surface soil.]

k Covering bed, large flints in stiff brown clay. [Trail?] 6 to 8 feet.

j Brickearth.

i-g, *e-c* Finely laminated loams and clays.

f Peaty black clay.

Beds *c-j* were 30 feet thick.

Prestwich. See 'Quart. Journ. Geol. Soc.,' Vol. ii. p. 107." Sir C. Lyell ('Antiq. Man.,' 1863, p. 161) also records finding them himself at this spot.

In 1867 Mr. George J. Smith got out of the gravel brought up from a shaft sunk near the railway-cutting, then being made, and close to the Downs Road, a number of shells referred to fifteen species, including *Corbicula fluminalis* and *Hydrobia marginata*. Unfortunately the section itself was not seen, and it cannot now be established whether these came from one stratum or from two, as in the former instance.

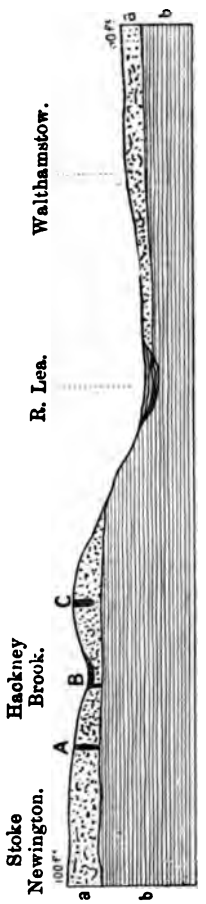


FIG. 18.—SECTION ACROSS THE VALLEYS OF THE HACKNEY BROOK AND THE LEA.
['Proc. Geol. Assoc.,' viii, 340.]
A Ayrsome Street. B Stoke Newington Common. C Stamford Hill.
a Gravels. *b* London Clay.

Specimens from Mr. Caleb Evans' collection, marked as obtained in Hackney and near Hackney Downs, present the peculiarity that many of the *Corbicula fluminalis*, and the *Pisidium astartoides* found in association with it are blue-stained, as though they had

been in contact with peaty beds, the only instance of the sort the writer is acquainted with. Mr. Tylor (1868, p. 392) speaks of the Unios as occurring in a bed of purple clay, with sands above and below them. In the same letter (p. 391) he describes a section in Highbury New Park, near Stoke Newington (afterwards alluded to by him as the Stoke Newington Pit), and gives a list of the shells therefrom determined by Mr. R. Tate. A figure of the

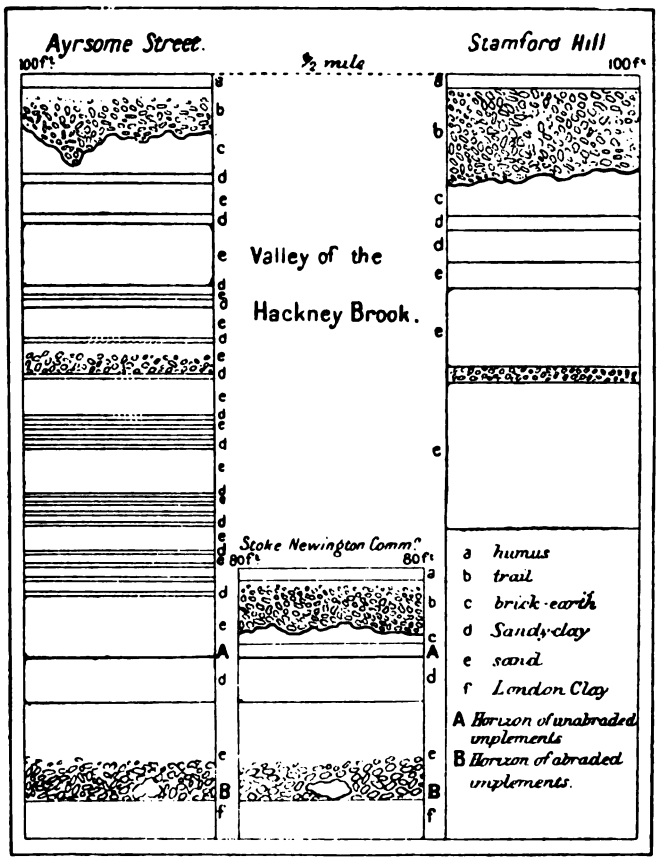


FIG. 19.—VERTICAL SECTIONS OF THE GRAVELS OF HACKNEY.

['Proc. Geol. Assoc.,' viii, 342.]

section (Fig. 17) appeared in his succeeding paper the following year (1869, p. 95), and the list of shells, with additional species

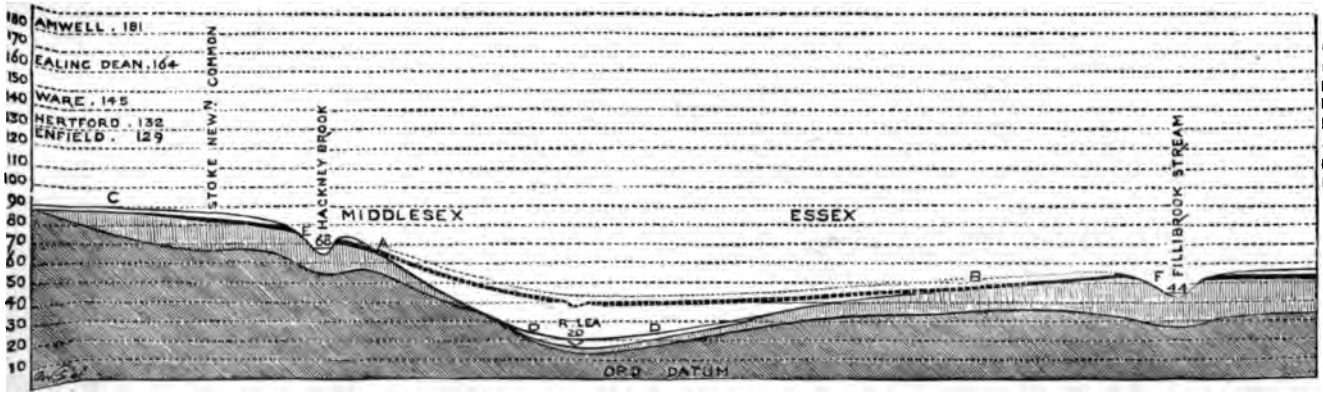


FIG. 20.—SECTION THROUGH THE VALLEY OF THE LEA, SHOWING THE POSITION AND ELEVATION OF THE PLEISTOCENE SHELL-BEARING DEPOSITS.

[Reprinted by kind permission of the Author, W. G. Smith, F.G.S., from 'Journ. Anthrop. Inst.,' xiii.]

Horizontal scale 2 in. = 1 mile. Vertical scale 1 in. = 100 ft.
Unshaded portions = Alluvial.
Vertical shading = River Drift.
Diagonal shading = London Clay.
The thick black line indicates the "Palæolithic Floor."

determined by Mr. J. Wood-Mason, was given in the table (*Ib.*, pp. 99-100). From this again *Corbicula* was absent.

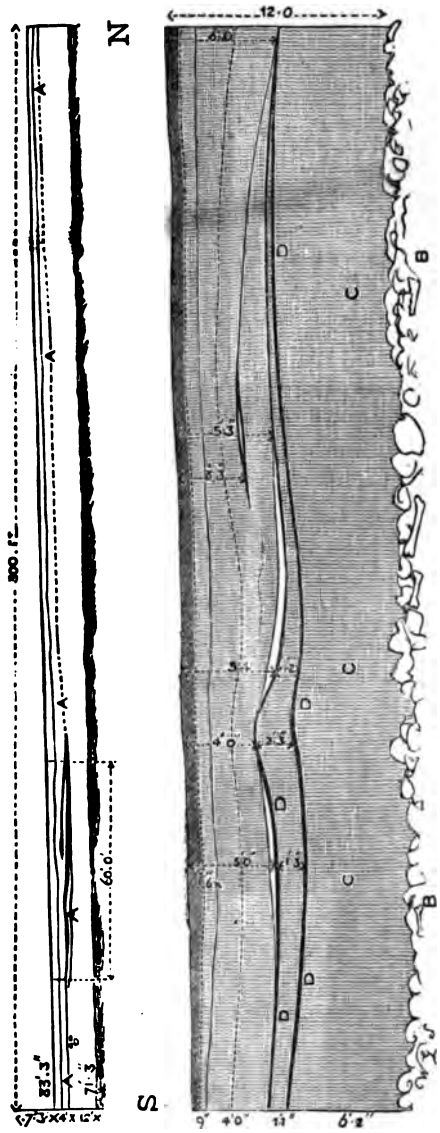


FIG. 21.—SECTION BETWEEN ALKHAM ROAD AND KYVERDALE ROAD, STOKE NEWINGTON.

[Reprinted by kind permission of the Author, W. G. Smith, F.G.S., from 'Journ. Anthrop. Inst.,' xiii. See also 'Proc. Geol. Assoc.,' viii, 127.]

The lower figure is an enlargement of the portion included between dotted lines in the upper one.

A A A } Palæolithic Floors above which is sandy loam—"Warp and trail."
D D D }
C Fine buff-coloured sand, often full of land and freshwater shells.
B The 12ft. gravel with rolled bones and Palæolithic implements.

There the matter rested till Mr. Worthington G. Smith, to whom we are indebted for the elucidation of the superficial geology

of this district, followed by Mr. J. E. Greenhill, took the matter up, and extended the observations from the Hackney Brook neigh-

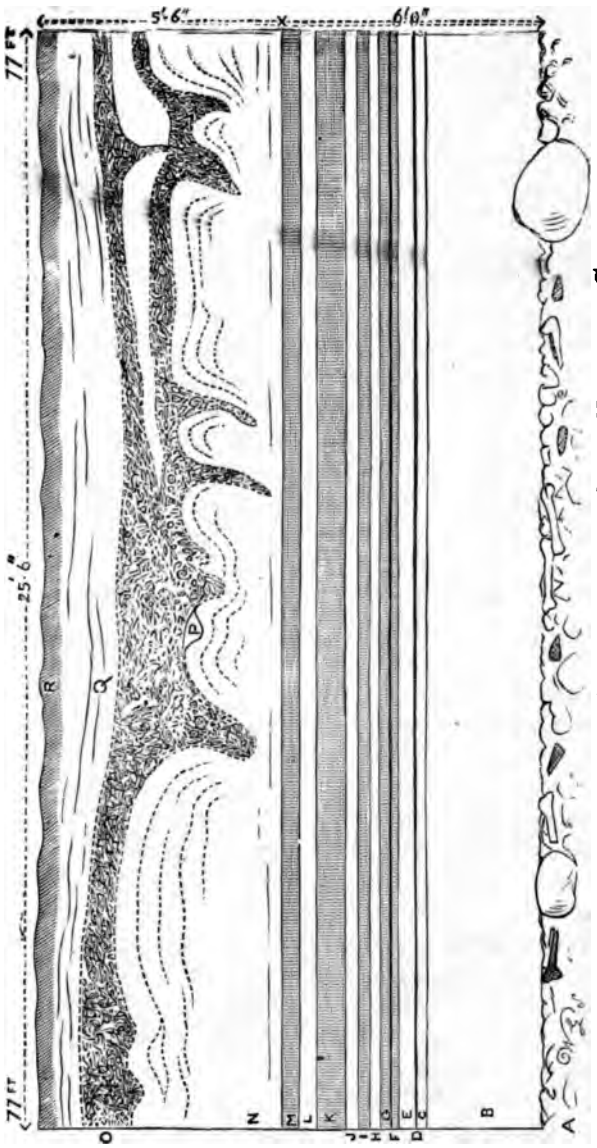


FIG. 22.—SECTION IN SAND-PIT EAST OF STOKE NEWINGTON COMMON.

[Reprinted by kind permission of the Author, W. G. Smith, F.G.S., from 'Journ. Anthrop. Inst.,' xiii. See also 'Proc. Geol. Assoc.,' viii, 128.]

B Humus. Q Mud of the "Trail." P Pocket of London Clay. O "Trail." C to M Sands and clays of different colours. B Buff sand, sometimes full of shells of land and freshwater mollusca. A The 12ft. gravel.

bourhood, where the sites first-named lay, to the Clapton area (Figs. 18 to 22), and though their main object was the pursuit of flint-

implements, the shells were not neglected, and three lists were published.

Of these the first was that by Mr. Smith (1882, p. 581, and 1883, p. 119), containing sixteen species only; the next of 33 species by Mr. Greenhill (1883, pp. 23-4), in which names from other lists had been incorporated; finally Mr. Smith (1884, pp. 368-70) issued a list of 45 species, which he described as "compiled from my own series, and from those published by Professor Prestwich and Dr. J. Evans." Dr. Evans, however, only cited the genera which had been quoted by Tate and Tylor in their lists.

Mr. Smith's specimens in the British Museum (some with Mr. Franks and the rest at Cromwell Road) have been gone over as well as Mr. Greenhill's own collection, and those from that of Mr. Caleb Evans already named. Mr. G. J. Smith's specimens, with Mr. Tylor's and Professor Prestwich's, are not to be traced.

The following species, the identification of which is open to doubt, are now struck out:—*Helix hispida*, *Limnæa glabra*, and *L. stagnalis*, all being given doubtfully by Mr. Pickering in Professor Prestwich's list. *Pisidium pulchellum* gives way to its synonym *P. fontinale*, and *P. obtusale* to *P. pusillum*, *Unio pictorum* being an error, undoubtedly, for *U. tumidus*, and *Planorbis carinatus* for *P. marginatus*. *Clausilia biplicata*, although it rests on Tate's determination, is far too uncertain to be included.

H. rufescens, given by Tylor on Professor Morris's authority, is doubtless an error for *H. concinna*. *Planorbis nitidus*, Müll., comprised two distinct species, and it cannot now be said which was present, though *P. lineatus*, Walker, is the commoner form. *Pupa umbilicata* is, in all probability, a slip for *P. muscorum*; whilst, as regards the *Achatina* (or, as it is now called, *Cæcilianella*) *acicula*, quoted by Mr. W. G. Smith, the only examples in his collection at the Museum are from near Brentford.

Eight species are retained on the authority of the first recorder, since there is no inherent improbability in their occurrence.

The following seven are added for the first time from the specimens in Mr. Greenhill's possession:—*Helix rotundata*, *Clausilia rolphii* (a single specimen), *Succinea elegans* (some of the specimens seeming nearer to this species than to *S. putris*), *Planorbis vortex* (from the clay beds), *Pisidium astartoides*, *Sphærium rivicola* (one fine valve—there is also a specimen marked *S. corneum* in the British Museum (Brit. Antiq. Dept.), which may prove to be a young example), and *Anodonta cygnea* (from the clay beds).

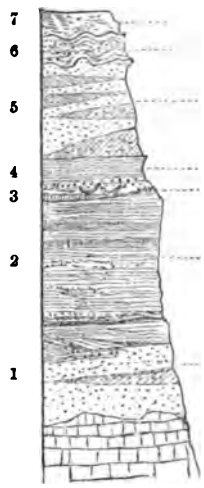


FIG. 23.—SECTION AT MR. PEARSON'S PIT, GRAYS THURROCK.

[Reprinted, by kind permission of the Author and of the Council of the Geological Society, from the 'Quart. Journ.,' Vol. xxiii.]

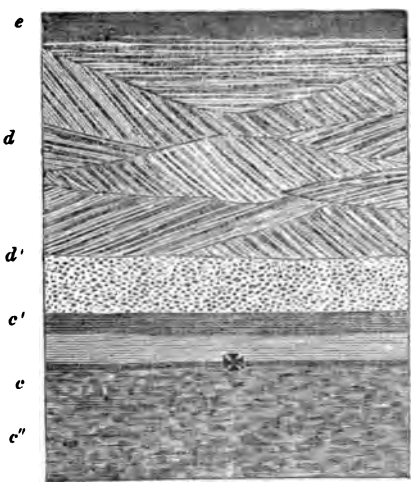


FIG. 24.—SECTION AT GRAYS, ESSEX.

[Reprinted, by kind permission of the Council, from 'Quart. Journ. Geol. Soc.,' Vol. xxv.]

Grays.—Although the Grays deposit was described by Professor Morris in 1836, the occurrence of shells was only briefly alluded to at the time, and the first list was published by him two years later (1838, p. 544). The next record is that given by S. V. Wood in his Monograph on the Crag Mollusca (1856, pp. 98-110 and 506-8). Another list was given by Professor Boyd Dawkins (1867, p. 100. Section see fig. 23), and in 1869 a revised version of Pickering's list (in Wood's Monograph) was issued by Mr. Tylor (1869, p. 99-100. Section see fig. 24).

Specimens from this classical locality have been examined in the British Museum, the Museum of Practical Geology, and the Geological Society's Museum; whilst Mr. Spurrell's collection, that of the late Caleb Evans, and those in Mr. W. J. L. Abbott's and in the writer's possession have helped to swell the list of authenticated specimens.

So full are the original lists, however, that only one or two species are added, and of these *Pisidium astartoides*, Sandb., was noted by S. V. Wood as the variety of *P. amnicum*, to which it had been proposed to give the name of *P. sulcatum*.

It has been considered desirable to eliminate several species from the table, viz.:—*Planorbis carinatus*, an error for *P. marginatus*; *Unio pictorum* and *Helix hortensis*, every specimen attributed to the former proving to be *U. tumidus*, and to the latter *H. nemoralis*; *Helix ruderata*, which can only have been an error of observation for *H. rotundata*; *Limax sowerbyi* [= *Amalia marginata*], since specimens under this name in the collection of the Geologists' Association are undoubtedly *L. agrestis*. *Clausilia biplicata* is far too doubtful to be admitted; whilst *Paludina vivipara*, given in one table, is probably a printer's error. *Achatina* [= *Cæcilianella*] *acicula* is given doubtfully in Tylor's list, and specimens are preserved in the Geological Society's collection; but they look so fresh that, seeing that the mollusc is a burrowing species which finds its way down to considerable depths (sometimes as much as 8ft.) from the surface, it is more likely than not to be an intruder, and therefore it is thought safer to leave it out.

Limnæa stagnalis, resting on the determination of that careful observer, Mr. Pickering, is given on his authority, as also *Hyalinia fulva*. *Planorbis nitidus*, as used by Wood, is a synonym for *P. lineatus*, and as such admitted; whilst *Vertigo substriata*, admitted on Tylor's authority, may possibly owe its appearance in his list to

the fact that *Pupa sexdentata*, quoted by Wood, is given by Forbes and Hanley as a synonym for that species as well as for *V. antivertigo*.

Unio littoralis is apparently very scarce at Grays, though a fine pair of united valves and two odd ones are in the British Museum (Natural History), and a few fragments in Mr. Spurrell's collection.

In addition to *Hydrobia marginata*, there are, in the British Museum series, a number of specimens ("G. 108") that must be considered a variety of *H. ventrosa*, including two extreme forms that resemble varieties of *H. ulvæ*. To the same species probably belongs the fragment of a fine example in the Museum of Practical Geology, marked "Rissoa?"

From this locality were first obtained those high-spired forms of *Valvata piscinalis*, to which, before their identity was established, the name of *V. antiqua* was given (Morris, 1838, p. 544 and 547). According to Dollfus (1884, p. 33 note), an almost identical variety is now living in the canals of northern France.

West Thurrock.—Here, in the pit belonging to the Tunnel Cement Works Company, Mr. W. J. Lewis Abbott found some shells in loamy clay, with sandy patches, that rested on a series of sands and gravels overlying the Chalk and abutting against an escarpment of the latter.

The list is not large, and the specimens are in a very fragmentary condition, with the exception of an abnormal example of *Helix ericetorum*. This specimen* was picked off the stuff that had been thrown down from the section, and must have come from one of the sandy patches mentioned. On first inspection it appeared to belong to some other species of the Xerophila group, and very close to *Helix instabilis*, Ziegl.; but after a prolonged examination and guided by the presence of a colour-band, there can be little doubt as to its identity. The other shells are:—

Pupa muscorum.	*Planorbis spirorbis.*
Limnæa peregra.	—— *marginatus.*
Planorbis corneus (?).	*Bythinia tentaculata.*

These are included with the Grays specimens in the table, since they come from the same series of beds.

Ilford. (Sections figs. 25 to 30.)—The Ilford deposits are

* Now in the Natural History Museum.

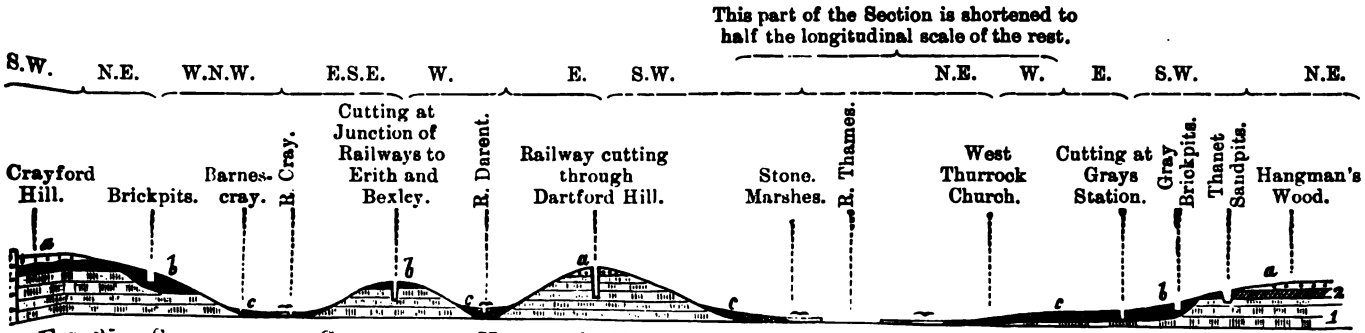


FIG. 25.—SECTION FROM CRAYFORD TO HANGMAN'S WOOD. Length: Nine miles along an irregular line. Prepared by Mr. S. V. Wood, F.G.S.

[Reproduced, by kind permission of the Editor, from 'Geol. Mag.,' 1874, p. 396.]

KEY TO GEOLOGICAL MAP OF ILFORD.
(*See opposite page.*)

- Alluvium.
- Brick-earth.
- Gravel.
- London Clay.
- Woolwich and Thanet Beds.
- Chalk.
- Roads.
- Railways.

1. The Chalk.
2. The Thanet Sand.

a. Thames Gravel of the Highest Elevation, which covers Dartford Heath.

b. *Corbicula* Brick-earth.

c. Gravel (with some Brick-earth).

Recent Alluvium.

N.B.—The *Corbicula* Brick-earth at both Grays and Crayford is partially underlain by Gravel.

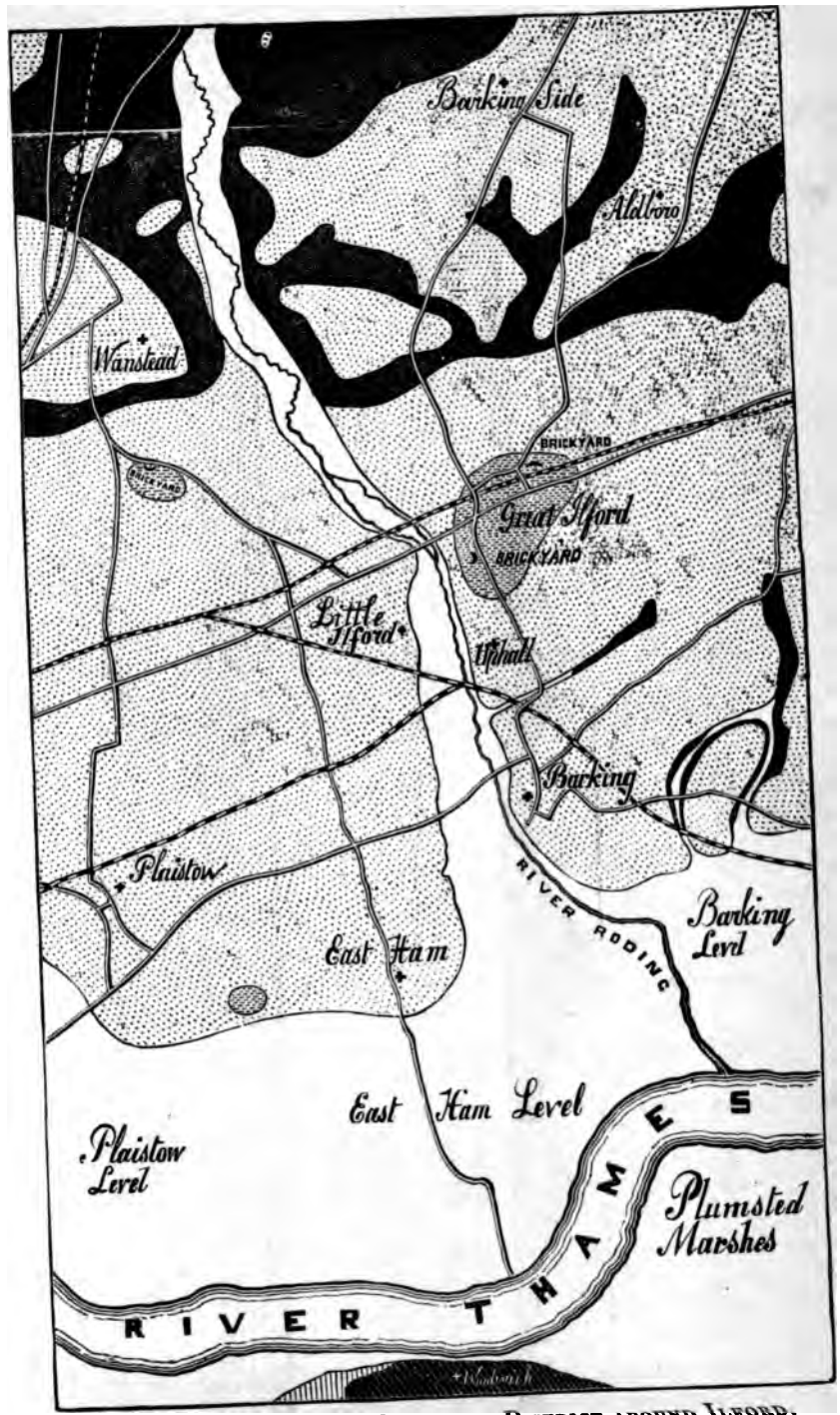


FIG. 26.—GEOLOGICAL MAP OF THE DISTRICT AROUND ILFORD.

[Reproduced, by kind permission of the Editor, from 'Geol. Mag.,' 1874, p. 287.]

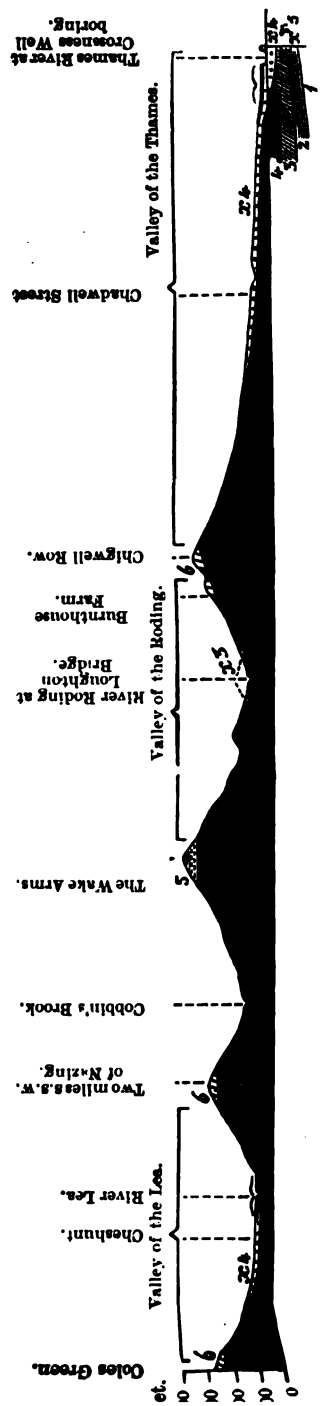


Fig. 27.—Section (after S. V. Wood) to show the position of the Thames Valley Beds relatively to the Glacial Beds of the Middlesex and Essex Heights.

[Reprinted, by kind permission of the Editor, from 'Geol. Mag.,' 1874, p. 394.]

1. Chalk.
2. Thanet Sand.
3. Woolwich Beds.
4. London Clay
5. Lower Bagshot.
6. Great Chalky Clay (Glacial).

x3. Gravel of the Roding Valley.

x4 } " " Lea and Thames Valleys.
x5. }

~ Alluvium.

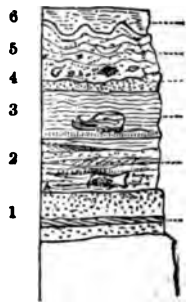


Fig. 28.—Section in the Uphall Brick-field, Ilford.

[Reprinted, by kind permission of the Editor, from 'Geol. Mag.,' 1874, p. 394.]

a. Clayey brick-earth, with *Corbicula fluminalis* and other molluscan shells.
b. Bright yellow sand, with *Corbicula*.
c. Newer gravel.
d. Humus, &c.

celebrated for having yielded, under the patient supervision of Sir Antonio Brady, the wonderful collection of mammalian remains that now repose in the Natural History Museum. The shell beds have unfortunately been worked out.



6. Surface-soil, from 1-3 feet.
5. Irregularly stratified brick-earth and gravel, 6 feet.
4. Irregular layer of flint-gravel, 1 foot.
3. Fine red and grey sandy loam, 4 feet.
2. Fine sands and chocolate coloured brick-earths, 6 feet.
1. Yellow sand and gravel.

FIG. 29.—SECTION AT UPHALL PIT, ILFORD, SOUTH SIDE.

[Reprinted, by kind permission of the Author and of the Council of the Geol. Soc., from 'Quart. Journ.,' Vol. xxiii.]

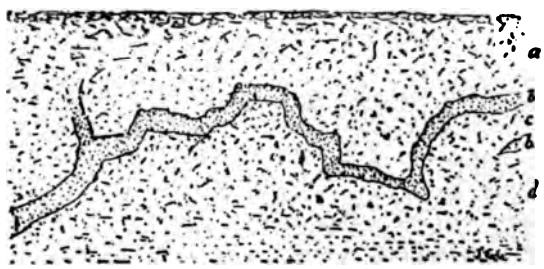


FIG. 30.—SECTION IN THE BRICKYARD ON THE SOUTHERN SIDE OF THE HIGH ROAD, ILFORD, 1888. (J. G. GOODCHILD.)

[Reprinted from 'Geol. Surv. Mem.,' London, Vol. i., by kind permission of the Controller of H.M.'s Stationery Office.]

a. Soil, etc.

b. Contorted seam of coarse brown sand, with more or less loam.

c. *d*. Brick-earth with *Corbicula fluminalis*, etc. Bedding obliterated above, clear and undisturbed below.

The first list of the shells was that given by Morris (1838, p. 544), when ten species were recorded. Just double that number of names were cited by Professor Dawkins in 1867 (p. 100), whilst others appear in that given by Tylor (1869, pp. 99-100) on the authority of Mr. Alfred Bell.

Concerning their occurrence, Dr. Cotton remarked (1847, p. 165):—"The two genera of shells, of which hundreds may

often be obtained at one visit, are *Helix* and *Cyrena*, but *Unio* and *Planorbis* are not uncommon, and *Ancylus*, *Succinea*, *Valvata*, *Limnæus*, *Cyclas*, and *Paludina* have been discovered. They are chiefly seen in the layers of sand upon which the brick-earth reposes, and beneath the bones, but are sometimes intermixed with them, and have been found even within their cavities; they appear to be partial in their distribution, and are not met with in the former cutting" [*i.e.*, N. side of London Road—Curtis' brickfield].

Specimens are preserved in the Natural History Museum, and in the Museum of Practical Geology, and there were a few in the collection of Mr. C. Evans. These establish twenty species, including five that have not before been mentioned as occurring in these beds:—

Helix pulchella. — *Planorbis albus.*
—— *fruticum.* — —— *lineatus.*
Bythinia leachii.

On the other hand, sixteen species have to be accounted for.

Unio pictorum may be dismissed at once, the species being *U. tumidus*. In the same way *H. hortensis* gives way to *H. nemoralis*, and *Planorbis carinatus* to *P. marginatus*. *Limnæa stagnalis*, there is reason to think, should have been *L. palustris*, and such was the opinion of Mr. Bell. The *Paludina vivipara* is another case of probable error, the only known example of the genus in these old gravels being the *P. contecta*, from Crayford, and it is therefore omitted from the table. *Unio littoralis*, too, though it is marked in Professor Dawkins' list, cannot be traced in any collection, and it is only copied into Mr. Tylor's list with a query, so that it has seemed best to leave it out. The other names are given for what they may be worth, on the authority of those chronicling them.

Amongst the additions, that of *Helix fruticum* (see Fig. 34, No. 7) is the most remarkable, its occurrence in the Thames Valley having hitherto been unrecorded. A single specimen was found by Mr. S. V. Wood at Stutton (1856, pp. 308-9), and the species was fairly common at Barnwell, near Cambridge.*

When the streams on which these several localities occur are traced to their sources, it will be seen that the Roding, the Stour, and the Granta (which joins the Cam just above Cambridge) all rise within a short distance of each other in N.W. Essex, so it

* 'Proc. Geol. Assoc.' (1888), p. 355.

seems a not unnatural inference that this species may have formerly had its head-quarters there, in which case the Essex Naturalists should look for it in the deposits of the Chelmer and Blackwater, which likewise rise in that area.*

Mr. W. Davies has noted† the frequent occurrence of numbers of shells of *Helix nemoralis*, etc., within the brain cavity of the skulls of oxen from this locality, and suggested that they may have found it a convenient place in which to hybernate whilst the skull still lay on the dry land. To this it may be added that the animal matter would remain longer within than without the skull, and that snails by no means despise animal diet, the flavour of which hanging about may have served as bait to attract them into what ultimately proved both trap and tomb.

In the Museum of Practical Geology are two shells of exceptional size from Ilford—an example of *Limnæa palustris*, measuring 29 mm. alt., and one of *Bythinia tentaculata*, 15 mm. high.

Crayford, Erith, and Stoneham. (Sections figs. 31 to 36.)—The deposits at Crayford and at Erith present such identical features and are so clearly, as shown by Mr. F. C. J. Spurrell, one and the same thing that no distinction need any longer be made between them. With the shells from these places may also be included the few common species found by Mr. Penning in gravels of the same age at the point where the Lewisham and Dartford loop line joins the old North Kent Railway close to Stoneham (Whitaker, 1889, p. 440).

Prof. Morris (1838, p. 544) was again the first to publish a list of species derived from Erith, whilst in the appendix to his paper (*ib.*, p. 547) appears the first identification, with a figure by Mr. G. B. Sowerby, of *Unio littoralis* as a British fossil. Morris' list contained but thirteen names, whilst there are now forty-two species definitely established for these River Drifts, of which ten are new. Prof. Dawkins (1867, p. 100. Section fig. 36) first recorded the species from Crayford and Erith separately, but of the twenty down only one was not common to both. Mr. Tylor's lists (prepared by Mr. A. Bell) brought the number up to a total of thirty for the two, whilst the relative distribution between them was by no means so level. Thirty-nine species are given in the table to their paper by Messrs. Cheadle and Woodward (1876,

* Mr. W. H. Dalton, 'Essex Nat.,' 1889, p. 10, mentions some Helices resembling this species being found at a point 7 m. N.W. of Colchester.

† 'Cat. Pleist. Verteb. Coll., Sir A. Brady,' 1874, p. 70.

pp. 97-8). A small list was also published of species procured at Erith by Mr. G. F. Dollfus (1884, p.39).

The present record is founded firstly and mainly on specimens

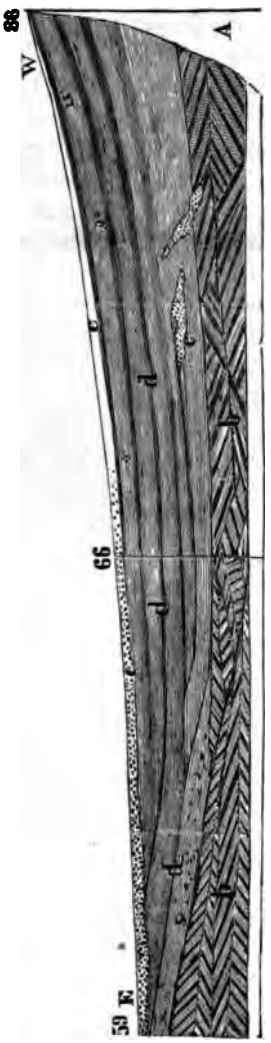
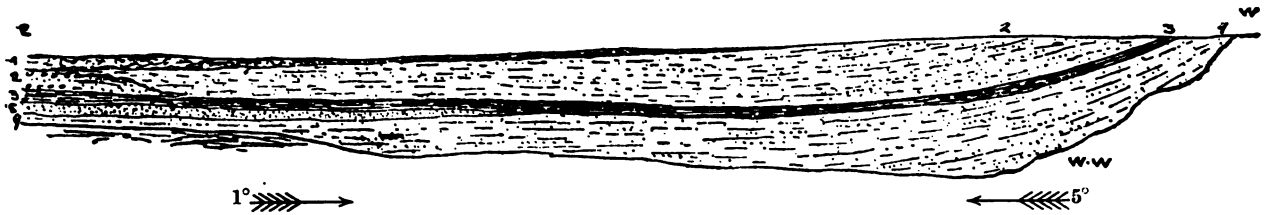


FIG. 31.—SECTION OF THE CORBICULA-PIT, ERITH.

[Reprinted, by kind permission of the Council, from 'Quart. Journ. Geol. Soc.,' Vol. xxv.]

A. Chalk.
b—e. Beds of River Drift approximately as in Fig. 24.

in the possession of Mr. F. C. J. Spurrell and the writer, supplemented by some from the collection of Mr. R. Nuttall, jun.;



The arrows show the amount of dip at the spots above them.

FIG. 32.—SECTION SHOWN BY THE SOUTHERN FACE OF THE GREAT PIT AT THE ERITH BRICKYARD, 1867.

[Reprinted from 'Geol. Surv. Mem.,' London, Vol. i., by kind permission of the Controller of Her Majesty's Stationery Office.]

1. Soil and wash, lessening westward.
2. Brown brick-earth, with race, about 15 feet. Contains pebbles, and pieces of shells from the Woolwich beds.
3. Darker Brown Clay, with a little race, about 5 feet, with a little grey Brick-earth (with shells) at the bottom, passing down into the bed below.
5. Sand with shells (*Corbicula fluminalis, etc.*) and pebbles, about 4 feet; loamy at top in parts and gravelly at bottom. Thins out as the ground rises westward.
9. Brick-earth with a little pebble-gravel.

The numbers correspond with those in Fig. 33.

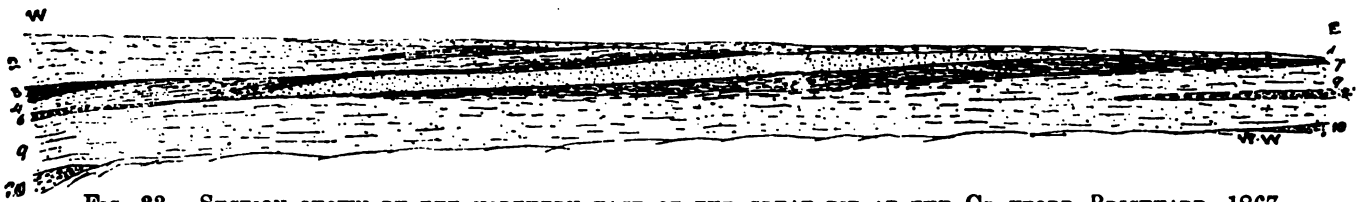


FIG. 33.—SECTION SHOWN BY THE NORTHERN FACE OF THE GREAT PIT AT THE CRAYFORD BRICKYARD, 1867.

[Reprinted from 'Geol. Surv. Mem.,' London, Vol. i., by kind permission of the Controller of Her Majesty's Stationery Office.]

1. Loamy soil and wash.
2. Brick-earth, about 12 feet.
3. Brown clay with race, about 3 feet.
4. Brick-earth, clayey, about 7 feet.
5. False-bedded, light-coloured sand (the shell bed), about 5 feet. *Corbicula fluminalis* very abundant.
6. Pebbly gravels, about 1 foot.
7. Brown clay, wedging out against—
8. A long lenticular bed of stiff, grey clay with race, over 4 feet.
9. Brown brick-earth, with race, 15 to 20 feet.
10. Sand and gravel false-bedded, with blocks of concretionary sandstone at top, 4 feet shown.

The numbers of the beds are the same as those in Fig. 32.

besides which the few specimens in the British Museum (Natural History),* and those in the possession of private collectors, such as Mr. Warburton, Mr. Harris, Mr. Abbott, Mr. J. Allen Brown, and others, have been examined, so that in this case the materials on which to found a satisfactory census are fortunately present in abundance. Moreover, since Mr. Spurrell's specimens are the identical ones from which the original lists were compiled, the task of eliminating errors which have been passed on from one table to another is both simplified and rendered a more certain one; though Mr. Tylor's specimens cannot unfortunately be traced.

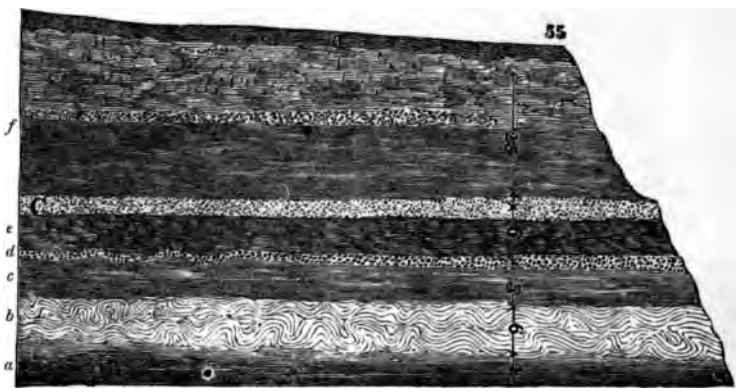


FIG. 34.—SECTION OF THE CORBICULA BED, CRAYFORD.

[Reprinted by kind permission of the Council from 'Quart. Journ. Geol. Soc.,' Vol. xxv.]

f. Laminated brick-earth, gravel, and loam, 25 feet, passing into Corbicula sand-bed C.

e. Brick-earth and Clay, 6 feet.

d. Pebbles from Woolwich series, brick-earth and clay, 6 feet.

c. Brick-earth, 5 feet.

b. Wavy laminated brick-earth, 6 feet.

a. Sands, 4 feet.

* A complete series has now been placed there.

The following names consequently are altogether removed: *Helix rufescens* (a misidentification for *H. concinna*); *Planorbis carinatus* (the specimen proving to be *P. marginatus*); *Hydrobia marginata* (which, though quoted in some lists from both Crayford

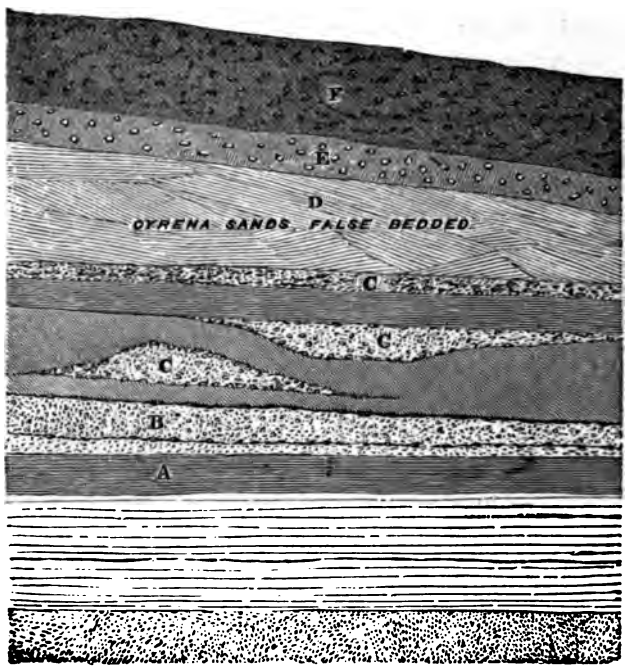


FIG. 35.—SECTION IN CRAYFORD PIT.

[Reprinted, by kind permission of the Council, from 'Quart. Journ. Geol. Soc.,' Vol. xxv.]

Length of Section 150 feet; height 30 feet. To show variation in the pebble beds C.

F. Covering bed [Trail?] (without shells).

D. False-bedded sand. Corbicula-bed from 4 to 6 feet.

B. C. & E. Beds with shells.

A. [Not defined].

and Erith, has never been found there, any more than has *Unio pictorum*); *Paludina vivipara* (the specimens being *P. contecta*); *Sphærium canaliculatum*, an error for *S. caliculatum* (= *S. lacustre*). *Helix cantiana* and *H. lapicida* were dead recent examples that must have been gathered up with specimens on the talus. The

following names disappear in favour of their synonyms: *Pupa marginata* (= *P. muscorum*); *Planorbis complanatus* (= *P. marginatus*); *Planorbis rotundatus* (= *P. spirorbis*); *Pisidium caliculatum* (= *P. fontinale*).

Zonites [= *Hyalinia*] *crystallina*, *Z. nitidula*, *Z. radiatula* and *Carychium minimum* are given on the authority of the first recorder.

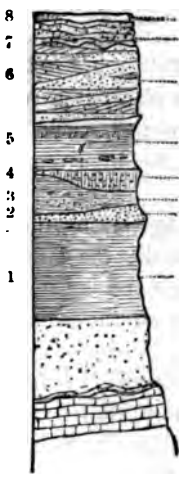


FIG. 36.—SECTION AT STONEHAM'S PIT, CRAYFORD.

[Reprinted, by kind permission of the Author and of the Council of the Geol. Soc., from the 'Quart. Journ.,' Vol. xxiii.]

The following appear for the first time :—

Helix arbustorum.	*Planorbis contortus.*
Cochlicopa lubrica.	—— *lineatus.*
Clausilia rugosa.	*Hydrobia ulvæ*, var.
Ancylus lacustris.	*Bythinia leachii.*
Planorbis glaber.	*Pisidium astartoides.*
—— *nautileus.*	

An amusing instance of the way in which errors may creep into a list is furnished by a letter from Mr. H. W. Kidd to the 'Bayswater Chronicle,' dated Oct. 25th, 1877, wherein is recorded the finding in a sample sent him from Erith by Mr. Cheadle of two small shells which were submitted to Mr. Sowerby, who recognized them as fry of *Fusus*. Mr. Cheadle, however, informs me that the sample in question was sent in a tin that had previously been used at the sea-side for collecting purposes, and amongst other gatherings had contained egg-capsules; being in a

hurry it was not cleaned out before the Erith material was packed in it. Hence the discovery of "marine shells in the Erith Brick-earths."

The most abundant species in these deposits is *Valvata piscinalis*, though it is closely rivalled in prevalence by *Pisidium amnicum*.

Several examples of this last show a curious mended fracture down the middle from the umbo of the valve to the margin, which is consequently indented; in the pairs both valves are alike broken, and since the injury is always in the same place, it would appear evident that it was due to mechanical causes, such as pressure from without, and not, as has been suggested by a young writer, to lesion from the action of a parasite.

The two examples of *Helix nemoralis* call for special mention, inasmuch as whilst both are very fine individuals, the larger rivals the biggest specimens from southern Europe and measures 21 mm. alt. × 29 max. diam., and 25 min. diam., the mouth being 15 × 15 mm.

Other individuals of large size are an example of *Paludina contecta*, from Erith, in Mr. Warburton's possession, that has a height of 31 mm.; and an individual of *Unio littoralis*, in the same collection, measuring 55 × 78 mm.

In Mr. Spurrell's series there is a valve of *Pisidium amnicum* 9 × 11 mm., and a complete pair of *Corbicula fluminalis* 33 × 37 mm., with a thickness of 18 mm. (Fig. 34, No. 3.).

One specimen of *Bythinia leachii* measures 7 mm. alt., and at first appeared as if it must belong to another species. It was referred to Dr. Böttger, who most obligingly examined it and confirmed the determination, as he also did that of some extremely dumpy varieties of *Limnæa palustris*. To the same great authority were submitted some examples of a variety of *Sphærium corneum* from these beds, which he considers to be absolutely identical with a rare German form now living in the Main, named by Kobelt *Sphærium mœnanum*.

Clausilia rugosa rests on a single specimen found by Mr. Spurrell: its state of preservation differs markedly from that of the majority of the other shells; but it came in all probability from one of the more clayey beds, whilst the mass of shells were collected from the sandy layers.

The state of preservation of the shells in the River Drift deposits.—Complete loss of all animal matter, rendering them

very friable, and absence of blue peaty staining, characterizes the shells from the River Drift. Two exceptions, however, are of interest: certain specimens of *Unio tumidus* in Mr. Greenhill's collection, that came from the very base of the series and were embedded in the washed-up London Clay, retain their periostracum in a most remarkably fresh condition; whilst the specimens from Hackney already alluded to are peat-stained.

Differences are perceptible in the specimens from the several localities. Those from Clapton and Stoke Newington are remarkably white; the Grays' specimens have a dirtier tinge, and are sometimes slightly iron-stained, whilst those from Crayford, Erith, Ilford, and Brentford are mostly iron-stained, the Ilford examples being somewhat redder in tinge. The Crayford and Erith specimens are frequently marked with dendrites, sometimes in quite pretty patterns, a feature which has not been observed in those from the other localities.

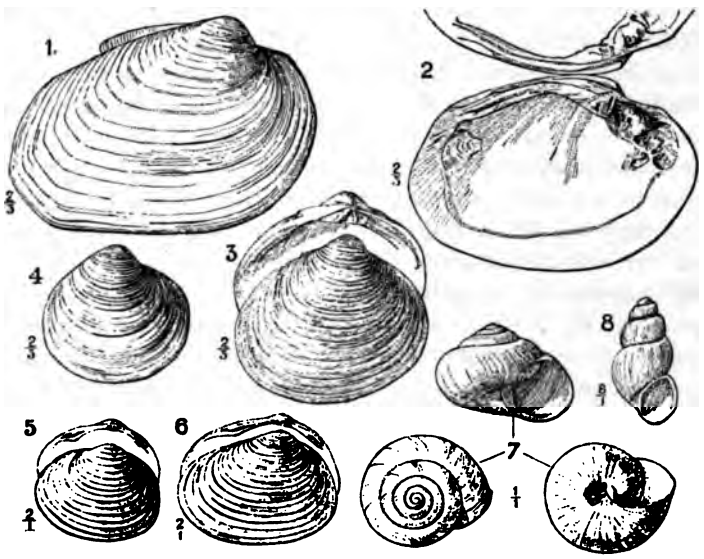


FIG. 37.—NON-MARINE MOLLUSCA FROM THE RIVER DRIFT (WITH THE EXCEPTION OF 6) EXTINCT IN BRITAIN.

1, 2 *Unio littoralis*, Erith.
3, 4 *Corbicula fluminalis*, Crayford.
5 *Pisidium astartoides*, Crayford.
6 *Pisidium amnicum*, "
7 *Helix fruticum*, Ilford.
8 *Hydrobia marginata*, N.E. London

(The original specimens are in the Natural History Museum.)

Notes on some of the species, etc.—Varieties when remarkable have been alluded to under the sections, whilst mere variations such as are common to all species, and which are identical with those met with in the living forms, call for no observation; they are taken for granted.

Certain main features, however, should not be passed over. Allied species which in the existing examples show passage forms are yet more difficult to separate in the fossil specimens where the approach is far closer, even if the differences be not bridged over entirely. This is the case with *Succinea putris* and *S. elegans*, and again with *Limnæa auricularia* and *L. peregra*.

Helix hortensis has not yet been definitely recognized, most of the fossil examples that used to be attributed to this species proving to be undoubtedly *H. nemoralis*, with which indeed it was at one time supposed to be identical, but this want of recognition may in part be due to the fact that when the characteristic colour-markings are absent there is at present no adequate means of distinguishing it.

Helix pomatia and *H. aspersa** are not found anywhere in pre-Roman deposits, though frequently found with Roman remains. They were probably introduced about that time. *Helix cantiana* was in all probability a still later introduction, for though everywhere most abundant nowadays, and plentiful on the Erith marshes, it nowhere occurs in any of the deposits, even the most recent.

Helix rufescens although frequently recorded from the River Drift, appears really to be typical of the Alluvium, since all specimens attributed to this species which have been examined from the former have proved to be either *H. concinna*, or sometimes *H. caperata*. *Helix concinna* is far more plentiful than *H. hispida*; and, though great doubts at present exist whether these are two species orone, still, since the extreme forms are so marked, it is found convenient to distinguish between them and to adopt the current names, though, according to Hanley the *H. concinna* of Jeffreys was the type of Linné's *H. hispida*, which type, alas, cannot now be found.

Some species, such as *Helix caperata*, seem to have been uniformly smaller in River Drift days than in the Alluvial and Recent periods.

* The single specimen recorded from the Kennet Valley is probably spurious. See 'Science Gossip,' 1883, pp. 115, 237.

On the other hand, speaking broadly, the Pleistocene molluscan fauna appears to have been finer than the existing one, as some of the dimensions quoted go to prove, and it really seems as if our non-marine mollusca had deteriorated both in size and number.

In addition to the five species extinct in Britain, there are two—*Helix lamellata* and *Succinea oblonga*—no longer found in the Thames Valley, though the latter is said by D. Cooper to have lived at one time in the Battersea marshes.* At the present day this species is very restricted, whereas formerly, judging from its occurrence in the various alluvial deposits all over the country, it must have been far more prevalent.

Planorbis glaber was likewise far commoner than now. It has been the fashion of late to try and identify this form with *P. parvus*, Say, an American species; but this is an incorrect determination. The types of both are in the United States National Museum; and Mr. W. H. Dall, when applied to, most obligingly took the trouble to examine all the specimens very carefully. He writes: "*Planorbis glaber*, Jeffreys, in my opinion is distinct from *P. parvus*. The latter is flatter and less deeply umbilicated, and shows much more of the whorls within the outer one. It is also distinctly less polished in the average specimen." An examination of the specimens he was so good as to send at the same time confirms this opinion.

Planorbis carinatus is another species which has been recorded from the River Drift, but which appears to be confined to the Alluvium. It was generally in early days put down instead of *P. marginatus*, which was mistaken for it.

Neritina fluviatilis may be called the characteristic shell of the Alluvium, being extremely common, not to say abundant, therein; whilst not a single example occurs in the older beds, in which *Corbicula fluminalis* is correspondingly plentiful. The two nowhere occur together.

Unio littoralis (Fig. 37, Nos. 1, 2) is curiously erratic in its occurrence. No specimen has been found in N.E. London, and though once recorded from Ilford, it was probably through a misprint.

Unio pictorum is, as Wood observes, very rare as a fossil. Two localities are cited by him—Grays and Cropthorne. Now the specimens from the former locality, in the British Museum, and those named by Pickering, in the collection of the Geologists'

* 'Mag. Nat. Hist.,' n.s., ii (1838), p. 478.

Association, are all *U. tumidus** ; the Cropthorne specimen, a single valve, is preserved in the Geological Society's Museum, and though the determination is correct, the specimen is in such a completely different state of preservation to that of the other shells from the locality as to warrant the conclusion that it got in from a higher and far more recent layer than that which contained the other shells.

U. pictorum does occur at Barnwell, and in the Upper Freshwater beds at West Runton ; nevertheless, so far as the Thames Valley is concerned, it must at present be held to be a late Alluvial species.

Corbicula fluminalis, when a number of specimens are examined from each of the localities, shows features characteristic for each.† Those from N.E. London are nearly exactly as broad as high, the average specimen measuring 18 mm. each way. The Grays' specimens are nearly all 2 mm. wider than broad, and much smaller in appearance, the average example being 14 × 16 mm. The largest specimen from this locality is one in the Natural History Museum : 19 × 22 mm. From Ilford they vary more, but average 1½ mm. broader than high, or 15 × 15·5 mm. Specimens from Crayford and Erith (Fig. 34, No. 3), again, like those from Grays, are broader than high, usually by about from 2 to 3 mm., but being larger the proportional difference is less, 19 × 21 mm. being about the rule. The form shown in Fig. 37, No. 4, is exceptional here.

What led to the extinction of this interesting species, that once had a wide range over Northern Europe and Asia, remains to be explained. That it bred in this country is certain, the shells of the fry being found, as well as individuals of all sizes.

Pisidium amnicum (Fig. 37, No. 6), again, shows variation with locality. Those from Crayford exhibit the lines of growth but faintly, whereas specimens from Grays or Clapton are very strongly marked. Specimens from Brentford and the Loop cutting, Crayford, are alike in being more swollen and having more prominent umbones than the average specimens.

Pisidium astartoides (Fig. 37, No. 5) was first observed by Sir C. Lyell in the fresh-water beds at Runton, and figured by

* There is a specimen in the Museum of Practical Geology (Cotton Coll. No. 2367) that bears a strong resemblance to *U. pictorum*. Unfortunately the interior is not visible, so that it is impossible to pronounce definitely what it is.

† *Conf.* Dollfus, 1884.

him in 1840 * as "*Cyclas* (*Pisidium*) *amnica*, var. ?" Dr. S. P. Woodward appears to have at one time certainly considered it a separate species, for a box in his collection, marked "*Pisidium sulcatum*, Grays," contained undoubted examples of *P. astartoides*, mixed with extremely sulcate varieties of *P. amnicum*, some of which can scarce be separated from the former. The existence of these passage forms, if such they be, from Grays, is the only possible cause of hesitation in adopting the species, for in other cases, such as those from Crayford, no such intermediate examples can be found. Moreover, the form in question is not met with except in the River Drift, and in association with *Corbicula fluminalis*, no example being quoted from the Alluvium or known living, though *Pisidium amnicum* is quite as common as ever. As a rule it is so readily separable from its congener that the two have quite as much right to be distinguished as have *Succinea putris* and *S. elegans*, or *Limnæa auricularia* and *L. peregra*.

Pisidium astartoides (Fig. 37, No. 5) is less elliptical than *P. amnicum* (Fig. 37, No. 6), and usually may be easily recognized by observing the lines of growth, which are equidistant throughout, whereas in *P. amnicum* they are, save in exceptional instances, fainter, and placed closer together at the umbo than towards the margin.

Summary.—On reckoning up the total number of species in each column of the table it will be seen that there are 135 living and seven extinct forms recorded as British, and that 111 of the former are noted as living in the area drained by the Thames and its tributaries. Omitting from the calculation the 12 species of slugs and *Vitrina pellucida*, the remains of whose small and delicate shells are scarcely ever met with, and counting in *Helix lamellata* and *Succinea oblonga*, which, though British, do not now occur in the area under discussion, there are exactly a round 100 species whose shells might be looked for in the Thames Valley deposits, so that the total number of occurrences in succeeding columns of the alluvial beds shows also the exact percentage of forms met with.

Of the seven forms met with in the British Pleistocenes, but not now living in Britain, five (Fig. 37) have been found in the Thames Valley River Drift, and when it is borne in mind that some forms which occur here now were in all probability not British subjects at that time, it seems fair to consider that the totals of

* 'Lond. and Ed. Phil. Mag.,' xvi, p. 364.

those columns also fairly represent the percentages. So that, even under favourable conditions, the number of species of a given non-marine molluscan fauna that may be looked for in the alluvial beds of such a river as ours does appear to exceed 50 per cent.

In the Essex alluvials possibly the average will, when worked out, prove to be somewhat higher, but then the streams there are far smaller.

In some cases the occurrences are most irregular, owing mainly, of course, to imperfect knowledge; thus six living forms—*Limax agrestis*, *Helix aculeata*, *H. ericetorum*, *Clausilia rolphii*, *Succinea oblonga*, and *Paludina contecta*—are only recorded from the River Drift.

On the other hand there are twelve species which are only found in the Alluvium, and of these some certainly were not inhabitants of Britain before that period; whilst no less than twenty-eight species, now living in the area, are not found in any of the alluvial deposits.

In attempting to deduce from the mollusca any conclusions respecting the age of the beds in which they occur, or the nature of the physical conditions under which these were formed, the greatest caution is of course necessary.

In the case of the Alluvium, any difference in age is, geologically speaking, unimportant, and all that need be said is that the Fulham, Whitefriars, Blackfriars, and Lea Valley peaty beds are newer than the sands with shells below the layer of peat at Westminster, which may be held to correspond with the lower beds at Crossness. (See Figs. 6 and 8).

When treating of the river drift series, however, there seems a little more to go upon, and hence the order in which the localities are cited in the table.

Omitting for the moment the Brentford and Ilford beds, which show the smallest returns, and looking at the critical species, we find that at Crayford the typical shell *Corbicula* is at its finest, whilst at Grays the average size is far less, and in N.E. London, though not quite so small, it is confined to quite the base of the series. This points to its gradual diminution and extinction. With it goes *Pisidium astartoides*. The shells from N.E. London and from Grays resemble each other in state of preservation, and specimens of *Corbicula* from both show faint traces of coloration; in both, too, we find *Hydrobia marginata* and *Unio pictorum*, forms which are not yet met with at Crayford,

fairly abundant, and may, therefore, be judged to be coming in for the Crayford beds have been far too well worked to allow of their having escaped notice had they been present. From these facts it seems fair to infer that, if anything, the chronological order is as given. At Brentford, though *Unio littoralis* and *Hydrobia marginata* have been found, no trace whatever has been discovered of *Corbicula*. *Sphærium rivicola* occurs there and in N.E. London, where it makes its first appearance; accordingly, Brentford is set down as being the latest of the river drift series, although the evidence is admittedly not all that could be desired.

Ilford remains to be considered, and here the shells in their state of preservation much more closely resemble those from Crayford than from any of the other brickearths. The *Corbiculæ* are in size nearest to those from Crayford, and while *Unio tumidus* has made its appearance, *Hydrobia marginata* is still wanting, as at Crayford; so that it seems not unnatural to place these beds between those of Grays and Crayford.

For purposes of comparison Mr. E. T. Newton has been good enough to draw up a table of the mammalian remains from Grays, Ilford, Crayford, and Erith (v. p. 388), and to these localities has been added N.E. London, from Mr. J. E. Greenhill's list (1883, pp. 22-3, sep. paper, p. 2), omitting *Alces machlis*, which the printer was probably responsible for.

The mammalian remains, as previously pointed out, cannot, of course, be relied on to the same extent as the molluscan, nor, taken alone, would they prove much in the present instance; still it is a curious circumstance that, granted the order of the beds to be that here urged, then there are certain forms present in the upper ones which are absent in the lower; and though in most cases these have been found in yet older deposits elsewhere, it does look as if the Thames Valley at one time knew them not.

When the test of relative levels is applied from approximate figures furnished for this purpose through the kindness of Mr. Spurrell, who intends shortly to publish them in detail, the foregoing arrangement of these various patches of brickearth by no means adjusts itself to the law; for whilst the Crayford beds rise from O.D. to 100ft., the Ilford and Grays, starting at the same point, go up to only 40ft. and 45ft. respectively; whilst the N.E. London series begins at the 50ft. contour and rises to nearly 100ft. above O.D.

The two lines of evidence thus stated are at variance, and the

question arises as to whether the palæontological or the orological one be the more correct in this instance.

To discuss this question adequately would require more space than can be conceded here; but a brief statement of what are considered the most probable conclusions may be permitted. These are:—

1st. That while the relative levels of the terraces in a river valley are a fair test of their ages under the ordinary conditions of an unimpeded flow, such is not the case when the waters have been dammed back so as to cause them to slowly rise up the sides of the valley till a lake-like expansion of the river ensues.

2nd. The relative ages of the deposits formed under these conditions at the different levels during the rise of the waters will be just the reverse of those thrown down under the normal state of affairs, *i.e.*, the highest will be the newest.—Both series may be present in a valley.

3rd. Such phenomena are of actual occurrence, the process being repeated time and again where the collection of the water is caused by the formation of a barrier through the accumulation of water-logged trees and decaying vegetation.

4th. That some such a cause must be held to have had its share in the formation of the brickearths of the Thames Valley. How else are those of Crayford, 100ft. thick, to be accounted for?

5th. The Crayford beds probably represent the complete series; the Ilford and Grays the more or less denuded remains of other patches; whilst the N.E. London deposits represent the high-water mark, and the Brentford beds the final position when the waters had again sunk to their old level.

6th. The mode of occurrence and condition of the shells certainly suggest quiet water deposition along the margins of a lake-like expansion of the river rather than the products of ever-recurring times of flood; and the variations observable in the examples of *Corbicula* from the several places under discussion—the proximity of which is such as to preclude the idea that differences of environment can alone be held accountable for them—indicate a lapse of time by no means inconsiderable.

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APPENDIX.

Table showing the distribution of Pleistocene Mammalia in the various River Drift deposits of the London area. By E. T. Newton, F.G.S., etc. With the addition of those from N.E. London.

	N.E. Lond.	Grays.	Ilford.	Crayford.	Erith.
PRIMATES.					
Homo	×	..	...	×	...
Macacus pliocenus, Owen	...	×	...	...	...
CARNIVORA.					
Canis lupus, Linn.	×	×	×	×	×
„ *vulpes*, Linn.	×	×	×	...	...
Felis leo, Linn.	×	×	×	×	×
„ *catus*, Linn.	...	×	...	...	...
Hyæna crocuta, Erxl., var. *spelæa*	...	×	...	×	...
Lutra vulgaris, Erxl.	...	×	...	...	...
Ursus arctos, Linn.	×	×	×	×	...
„ *horribilis*, Ord.	×	×	×	×	...
UNGULATA.					
Bison bonasus, Linn., var. *priscus*, Boj.	×	×	×	×	...
Bos taurus, Linn., var. *primigenius*, Boj. ...	×	×	×	×	×
Capreolus caprea, Gray	×	×	×	...	...
Cervus elaphus, Linn.	×	×	×	×	×
„ *giganteus*, Blum. (= *Megaceros hibernicus*, Owen)	×	×	×	×	×
Elephas antiquus, Falconer	×	×	×	×	×
„ *primigenius*, Blum.	×	×	×	×	×
Equus caballus, Linn. (= *E. fossilis*, Meyer) ...	×	×	×	×	×
Hippopotamus amphibius, Linn. (= *H. major*, Owen)	×	×	×	...	...
Ovibos moschatus, Zimm.	...	...	...	×	...
Rhinoceros antiquitatis, Blum.	×	...	×	×	×
„ *leptorhinus*, Owen	×	×	×	×	×
„ *megarhinus*, Christol	×	×	×	×	...
Sus scrofa, Linn.	×	×	...	...	...
RODENTIA.					
Microtus amphibius, Linn.	×	×	×	×	...
„ *ratticeps*, K. & B.	...	...	...	×	...
Castor fiber, Linn. (= *C. europæus*, Owen) ...	×	×	×	...	...
Spermophilus erythrogenoides, Falconer ...	...	...	...	...	×
„ sp.	...	...	...	×	×
INSECTIVORA.					
Sorex sp.	...	×	...	...	...

BRITISH NON-MARINE MOLLUSCA.		ALLUVIUM. (Recent and Neolithic.)														RIVER DRIFT. (Palæolithic.)				
Cochlicopa (Zua) lubrica, Müll.	...	×	×	...	...	×	×	...	...	×	...	×	...			...		×		×
Neritina fluviatilis. Linn.	... ...	×	...	×	...	×	...	×	×	×	×	×	...	×	×	...	...	..	...	...
B. *PELECYPODA*.																				
Dreissensia polymorpha, Pall.	... ...	×	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
Unio littoralis, Lam.	... ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	..	×	...	×
—— *pictorum*, Linn.	... ...	×	...	...	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...
—— *tumidus*, Retz.	... ...	×	×	...	...	...	...	×	×	...	×	Sp	...	×	×	×	×	×	×	...
—— *margaritifer* Linn.	... ...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...
Anodonta cygnæa, Linn.	... ...	×	...	...	...	×	...	...	...	...	...	×	...	...	...	M	×	×	D	×
Corbicula fluminalis, Müll.	... ..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	×	×
Sphærium riricola, Leach.	... ...	×	...	×	...	...	...	...	×	E	...	...	...	...	...	×	×	...	...	...
—— *corneum*, Linn.	... ...	×	×	...	×	×	...	×	...	×	×	×	×	×	×	M	×	×	D	×
—— *orale*, Fér.	... ...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
—— *lacustre*, Müll.	... .	×	×	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...
Pisidium amnicum, Müll.	.. ...	×	...	×	...	×	...	×	×	×	×	...	...	×	×	×	×	×	×	×
—— astartoides, Sandb.	... ..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	×	×	...	×
—— *pusillum*, Gmel.	... ...	×	...	×	...	×	...	...	×	×	...	...	...	...	×	...	P	W	..	×
—— *nitidum*, Jenyns.	... ...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...
—— *fontinale*, Drap.	... .	×	×	×	...	×	...	×	×	×	×	×	...	×	×	×	×	×	×	×
—— *roseum*, Scholtz.	... ...	×	...	...	..	...	...	...	...	...	...	...	...	...	...	...	..	...		...
Totals ..... Living	135	111	24	17	11	30	12	25	15	39	20	43	8	40	46	21	39	46	28	43
Totals ..... Extinct	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	3	4	2	3

6 Species no longer living in Britain occur in the River Drift.
2 „ „ „ „ „ the Thames Valley occur in the Alluvium.
5 „ now living in the Thames Valley have been found fossil in the River Drift *only*.
12 „ „ „ „ „ „ „ „ „ „ „ „ Alluvium *only*.
28 „ „ „ „ „ „ „ not been found fossil at all.

B. = on the authority of T. Belt.
Bl. = „ „ „ „ W. T. Blanford.
D. = „ „ „ „ Prof. W. B. Dawkins.
E. = „ „ „ „ C. Evans.
G. = „ „ „ „ J. E. Greenhill.
M. = „ „ „ „ Prof. J. Morris.
P. = on the authority of Prof. J. Prestwich.
S. = „ „ „ „ G. J. Smith.
Sp. = „ „ „ „ F. C. J. Spurrell.
T. = „ „ „ „ A. Tylor.
W. = „ „ „ „ S. V. Wood.

EXCURSION TO THE SOUTH ITALIAN VOLCANOES.

By H. J. Johnston-Lavis, M.D., F.G.S.

(*Read January 3rd*, 1890.)

On Tuesday, September 17th, at Messina, the son of the late Prof. Seguenza and Messrs. Platania, of Acireale, met the party, and acted as directors. The steep escarpment of Taormina, composed of Triassic and Liassic strata, which have given rise to much controversy, was examined in the walk up to the town from the station.

Early the next morning the members of the excursión returned by train to Messina, to embark on the "Villa San Giovanni," a small private steamer hired for the week's trip to the Lipari islands. Just after mid-day we steamed out of the harbour and through the Straits, obtaining a splendid view of Scilla, with the lofty triple-stepped mountain of Aspromonte, which probably owes its configuration to as many planes of marine denudation. The port of Lipari was reached at sunset, when some of the less seaworthy members landed to pass the night. A portion of the party walked to the south end of the island to watch the explosions from Vulcano, and were repaid by seeing one dust-cloud give out many flashes of lightning. The next morning (September 19th), weather being favourable, we steamed out soon after sunrise and reached Stromboli early in the forenoon, where the ascent was made on the east side of the Sciarra. The summit was reached by a climb of about three hours, with short interruptions during which the party helped themselves to the splendid grapes from the vines through which much of the track lay. At the top I pointed out the sites of one or more ancient craters, as well as the peculiar position of the present vent, which occupies a situation similar to that of a parasitic cone, at a high elevation, but yet a considerable distance below the mountain summit. On account of the great depth of the sea at the north foot of the island, all the ejected materials that cannot remain at their maximum angle of repose roll down to the sea and continue their course onwards to the submarine foot of the cone. Five of the party photographed the crater from the overhanging summit. There were five active blow-holes, or small vents and cones, each of which from

time to time ejected with considerable violence showers of hot, pasty lava fragments, often accompanied by splendid vortex rings of smoke. The party then descended to the level of the vents on the west side of the Sciarra, from which also a fine view and many photographs were obtained. The westernmost vent showed a small quantity of pasty lava oozing from it for a metre or two, and then breaking off in pieces, which bounded down the steep slope of the Sciarra to the sea. Many augite crystals were collected, and the party then descended over a steep talus of sand and winding paths to the town, and embarked on the steamer. The ship steamed round opposite the Sciarra, where, two hours after dark, the monotony of the peculiarly hard bread (compared by some to trachyte) was relieved by the splendid display of Nature's fireworks.

At daybreak we steamed for the islets of Basiluzzo, Datolo Lisca Bianca, Lisca Nera, and Bottaro, on some of which a landing was made, and a few of the members attempted to see the Caldaje, a well-known submarine fumarole, but owing to the roughness of the sea its exact position could not be made out. The party then landed on Panaria, where the typical liparite is seen to perfection. There I drew the attention of the members to the very large number of worked obsidian flakes which are met with in the surface soil, though no natural source of this rock occurs at the island. These, together with numerous little Greek statuettes of household gods, indicate the colonization of this island in very early times. On a visit to Lisca Bianca also, some years since, I found a small number of obsidian flakes on that island. At Panaria the party collected a considerable number of flakes and a few implements.* The same evening the port of Lipari was reached, and as the steamer coasted along

* From the house top on Panaria, where the party had breakfasted, a fine view of the neighbouring islets could be obtained. I drew attention to the fact that Panaria, Basiluzzo, and the other islets constituted a volcanic pile, chiefly submarine but which in many respects might be compared to Lipari itself. In fact, were the sea bottom raised a few fathoms, an island of very considerable extent would be formed, the higher eminences of which would be constituted by the few patches of dry land we saw before us. Panaria and Basiluzzo represented two enormous domes of a highly acid trachyte or rhyolite or liparite, as variously named, which had oozed forth in a highly pasty condition without much explosive action. Some portions of the magma were less glassy than others, and as these had been drawn out just as the layers of butter and dough in a flaky pie-crust, they had produced a similar stratified structure at these two islands. If you compare the appearance of the natural section of Basiluzzo with the artificial experiment of Prof Reyer ('Theoretische Geologie," Stuttgart, 1888, Fig. 153, p. 152, copied into Prof. Judd's 'Volcanoes,' Fig. 43, p. 126) you will notice the striking resem-

the east coast of that island those on board were able to examine the principal geological features as they were pointed out to them. From north to south these are the great white crater of explosion of Campo Bianco, and the enormous obsidian stream that afterwards welled out from it, breaching it to the north-east, and flowing down into the sea, now known as the Rocche Rosse and Punta della Castagna. The far greater height of the south wall of the crater, with its peculiar hump, now known as Monte Pelato, I pointed out as due to the explosion occurring on the side of an old dolerite cone, which, covered by the essential ejectamenta of the Campo Bianco crater, constitutes this Monte Pelato. This structure is revealed in the sea-cliff where the relations of the dolerite and white pumice are well seen. Farther to the south, the geologists were shown another obsidian stream which issued on the east side of Mte. St. Angelo, and flowed nearly down to Canneto. The next to attract attention were the twin cones of Monte Rosa and their peculiar imbricated slopes, due to the interstratifications of streams of dolerite with scoria and other fragmentary deposits, which were being undercut by the sea. Finally, the spherulitic rock upon which the Castle of Lipari was built, was also indicated.

A visit to the Island of Vulcano, which has been in a state of eruption since August 3rd, 1888, was the business of the next day. Landing at the Porto di Levante, the first thing that struck the attention of the party was Mr. Narlian's cutter with its side staved in by one of the projectiles at the beginning of the eruption, although the boat was more than a kilometre distant from the crater. The holes in the roof and walls of Mr. Narlian's villa, the desolation of the vine-plantation and broom scrubs, many of which had been kindled and burnt by the red-hot projectiles, and the deep layer of grey volcanic dust on everything, formed a striking picture of the desolation caused by a small eruption of a small volcano. As we approached the foot of the cone we were impressed by the projectiles scattered about in large numbers, many of which were of great size. One still hot, and therefore recently ejected, was about a cubic metre in size and

blance of the two. In fact, there is good reason to believe that important geographical changes have been brought about in historic times, and we have indisputable evidence of endogenous activity in the solfatara of Lisca Bianca and the fumarole of Le Caldaje.

nearly a kilometre in a straight line from the crater. Most of these bodies consist of a mass of very acid obsidian pumice, covered by a crust of obsidian, cracked and bent up in a very curious manner, which I have described elsewhere as *bread crust structure.**

This I pointed out to be due to the obsidian reaching that intermediate stage between a liquid and a solid, or in other words a state of intense viscosity, like slightly warmed sealing-wax or hardened Canada balsam, which break when exposed to strong and violent mechanical stress, but bend under a slight and gradually applied one. The magma in the upper part of this volcanic chimney seems to be in this critical state, and, as the vapour collects and escapes from the more heated and fluid portion beneath the upper part, is broken in fragments and ejected, when it is relieved from the surrounding pressure and allowed to expand. The crust has cooled along the cracks before this, and continues to do so, as it is whirled through the air, and after its fall, whilst the interior expands at the same time, innumerable vesicles being formed from the water dissolved in the magma separating as steam. This expansion causes the cracking of the hardened crust, and in some cases protrusion through the crust. This expansion is proved not only by the cracking and protrusion, but also by the bending out in some cases of pieces of the crust and the drawing asunder of crystals, pieces of ancient dolerite and other rocks included in the magma, and attached to the walls of a vesicle.

The presence of these numerous projectiles, called "bombs" by some, was a warning; so the ascent to the crater was requested to be done in open order. After a tiring scramble, we reached its north-west edge. The old, deep crater is now replaced by a much shallower one, the sides and bottom of which are covered by obsidian dust, sand, lapillo, and projectiles of different kinds.

At the bottom we noticed a number of small, shallow, funnel-like pits in the sand, but no indication whatever of any activity, so much so that an unwary visitor might walk across it and probably notice nothing but a very high temperature. From time to time part or the whole of this crater-bottom is raised up by explosions of vapour and the essential eruptive material into

* H. J. J. L., 'The Recent Eruption of Vulcano.' 'Nature,' Vol. xxxix, p. 173, and "Further Notes on the Late Eruption at Vulcano Island," *ibid.*, Vol. xxxix, p. 109.

vast columns of dust, which rise to ten or more times the height of the volcano. Most of the coarser materials fall back into the crater, the distribution at a distance of the finer dust depending upon the force of the explosion and that of the wind.

During the greater of these explosions the bread-crust bombs are ejected to a considerable distance and electric discharges take place, which some of the party, who were fortunate enough to see one in the evening, described as having a peculiar green tint. We were able to remain at the crater's edge for two or more hours, during which upwards of a dozen explosions occurred, many of which five of us who were photographers have been able to register. We were at last driven away by a much more violent outburst, but on our way down did not fail to examine the fumaroles at the outer crater edge on the east side of the old obsidian stream. These were very active, giving out much vapour under pressure and depositing an abundance of realgar and sulphur and a little boracic acid.

The party then proceeded to the alum caves of the Faraglioni, whilst some bathed in the hot mineral streams gushing out on the shore close by, one well-known Professor of Mineralogy being very enthusiastic in collecting specimens of coquimbite, halotrichite, voltaite, and other rare alums in an exceedingly light Adamic costume, and fortunately for him no hand camera was in the vicinity. The triple-cratered doleritic cone of Vulcanello projecting from its plateau of lava, the formation of which has for the major part taken place in historic times, was next ascended and examined. As the different points were visited, the director explained the main features of interest, which will be reserved for a separate communication, they being too long to introduce here. After a very successful day the party embarked, with a rich collection of bombs, alums, and other specimens, on their return to Lipari, where the night was passed.

September 22nd was devoted to a trip on the Island of Lipari. Starting on mules and donkeys, we directed our steps to the east slope of Mte. St. Angelo, an old cone truncated by a crater of explosion. From the east side, at a very recent period, possibly historic, as the name would indicate, a stream of spherulitic obsidian oozed forth and flowed down the slope as a great, thick, viscous mass, known as the Forgia Vecchia, reaching nearly to the beach. Comparatively little explosive

action seems to have preceded its outpouring. Over the actual vent are a few small craterets with diminutive rings of fragmentary material, which were formed towards the end of the eruption, and in one crater are the remains of the old gas-fissure from which the last emanations occurred, depositing on its walls hæmatite and granular fiorite. Quitting this point, the deposits of white pumice derived from the Campo Bianco crater begin to form a thicker and thicker covering as we approach that old eruptive centre. Soon the sunlit glittering snow-white flanks of Mte. Chirica stood looming out against the background of the blue sea. Here I was able to point out that these mountains, like the original Mte. Pelato, are dolerite cones simply covered with a mantle of white pumice, which in some points has been denuded off. A peculiar yellow band, representing an old vegetable soil, is here met with, dividing the upper white pumice of the Campo Bianco eruption from an older one of the same material, the point of origin of which is not clear without long and careful study of the intricate overlappings of different eruptive deposits.

The grand crater of Campo Bianco with its wall of white pumice deeply interested all the party. This locality, which supplies all the first-class pumice of the world, is drilled by thousands of tunnels made in search of the larger morsels. The value depends on the practically total absence of any porphyritic crystals, which, from their greater hardness, would stand out and scratch the surface being polished. The view I offered of its formation was this:—Beneath this point there existed a fissure or canal filled by a completely fused acid glass in which separation of "formed material" in the shape of felspar or other crystals had not commenced. The glass in the upper part of the conduit had gradually dissolved or absorbed a considerable quantity of water from the more superficial and aquiferous strata until the increased tension was sufficient to overcome the superincumbent pressure. A gigantic explosion was the result, drilling out the side of the old dolerite cone of Mte. Pelato, the first essential eruptive material being nothing more than the scum or froth of the glass caused by the conversion of the water dissolved in it into the state of vapour on the relief of pressure, just as separation of carbon-dioxide blows out part of the champagne when the cork is removed. Behind there is, more and more gradually welled up, the less aquiferous glass which breached the crater to the north and poured forward into the

sea, forming a great promontory. The outer portion, which cooled more rapidly, remained a more or less pure obsidian, whilst the interior was able to undergo an imperfect crystallization, so that the whole mass has become an intricate spherulitic mass. As at the Forgia Vecchia, the last eruptive act is represented by the small unimportant crater-rings around the source and a few blow-hole craters. Some members made the ascent of Mte. Pelato along the crater edge, upon which a very large mass of black obsidian has been projected by one of the last explosions, which is interesting as showing the conversion of the fragments formed by its collision with the ground into bread-crust bombs.

A descent was made along the east side of the Rocche Rosse obsidian stream to the beach, where the deposits of commercial pumice-stone were examined, after which we embarked on our steamer, which had come to meet us, the mules returning by the paths.

The following day was devoted to the Island of Vulcano Starting early from Lipari, we steamed along the east coast of Vulcano, landing just beyond the Pta. dell' Asino. The ascent to the great platform over the steep slopes was very tiring, as the track lay over the loose dust recently ejected, and nearly every broom, brush, or tree was dead or stripped of leaves, and the day a very hot and oppressive one. At the height of about 450m., we passed a notch in the crater rim near the Pta. della Trovatina, where ancient, very finely stratified, dust beds are seen to perfection, traversed by an old radial dyke. Just beyond this point we rested in the shade of a few still surviving broom trees, and obtained a number of photographs of the explosions from Vulcano. Thence we proceeded to a small farmhouse, where a few grapes that had been able to resist the destructive effect of the falling volcanic dust were very acceptable. Close by I drew the attention of the party to a group of small olivine-basalt cones, La Sommata, where a number of beautiful, fusiform bombs and pieces of finely corded lavas were collected. This was a good point to give a general outline of the structure of the island, so far as two short visits have permitted me to make it out, and as it differs from the very simple arrangement we read of in text-books, it is perhaps worth repeating.

At a distant period two great cones grew up, that to the north-west of a line from So. dell, Arpa to Mte. Luccio being composed of trachytic rocks, and that to the south-east of

doleritic rocks. Which of these came first it is difficult to determine without a very detailed study, and it is not unlikely that they were contemporaneous, as Vulcanello and the present active cone of Vulcano have been. One or more grand explosive eruptions then truncated somewhat eccentrically to the north-west the great dolerite cone of the south half of the island. At a later date, one or more explosive eruptions likewise truncated the trachytic cone of the north half of the island somewhat eccentrically to the north-north-east of the original axis. Much of the filling up and conversion of the south crater into a raised plateau may be attributed to the materials ejected from the north crater. On this crater-plane fresh eruptions took place at Mt. Saraceno, at the junction of the two ancient explosion crater rings. From this cone part of the lavas poured down on the great crater-plane, Il Piano. Other outpours of basalts, with the formation of the cones of La Sommata, all helped to raise the floor of the great explosion-crater of the south half of the island to a plane. From the bottom of the crater of explosion in the trachyte cone, a new and at present active cone grew up, the later products of which are acid rocks, chiefly varieties of obsidian and its allies. In historic times, some distance to the north of the island, in the straits separating it from Lipari, eruptions of dolerite lava, scoria, lapillo, and dust took place, forming the present triple-cratered cone of Vulcanello with its surrounding platform of lava.

After a rough scramble the party descended to the Porto di Levante, embarked on the steamer, and steered for Messina, in the port of which town we passed the night.

Early the next morning, September 24th, we steamed out of the Messina harbour, and, after quitting the whirlpools, were much troubled by an increasingly rough sea, so that our hope of reaching Acireale and landing there was given up before we reached Taormina. The effect of sea-sickness on the majority resulted in the captain being ordered to land us at the first sheltered point. The operation of disembarkation, the finding of an ox-cart, and the transport of our luggage over part beach and part road to the Giardini Station, and our collapsed selves, must have presented a serio-comic side to the few observers of this group of disciples of Vulcan retreating from the domination of Neptune. That evening we arrived in Acireale and found ourselves once more amidst comparatively civilized life. There we were met by Prof. O. Silvestri, of Catania, and his son, who seems

to be a worthy pupil of his father. Here I handed over the reins of direction to Prof. Silvestri, satisfied that they were in more competent hands, the more so that I was really very ill. Messrs. Gaetano and Giovanni Platania—the former a Member of our Association, and an old travelling companion of mine in the Aeolian Islands, who had been of so much assistance in directing the party there, not only still continued to do so here, but in their native place of Acireale—rendered us most valuable services.

The following day we took carriages to Zafferana, and then, some on foot, others on mules, we ascended into the Val di Bove, Prof. Silvestri lucidly indicating and describing the important geological points along the way, such as the lava cascades of Val Calanna, the configuration and limits of the Val di Bove, the parasitic cones and lavas occupying its floor. Beneath the escarpment under Mt. Pomiciaro we were able to examine some of the radial dykes, the lava streams, and numerous other points of lithological interest. This was followed by an "al fresco" lunch, which unfortunately was cut short by a storm. A number of us pushed through the driving rain to near Lyell's axis of Trifoglietto, from which point the sight is imposing, especially with the addition of the drifting clouds.

The same evening the excursionists had been offered a banquet by the municipality of Acireale, and on their return from the Val di Bove were pleasantly astonished on their entry to the town to find it artistically illuminated in their honour. After dinner, during which the very fine town band had played a series of pieces, toasts were drunk by some of our members, and replied to by the Sub-Prefect, the Syndic, and Messrs. Platania. This small, but pretty and clean town owes much to the late well-known Baron Panisi, who founded here a meteorological and seismological station, and in many other ways has been active in making Acireale, with its grand hotels and thermomineral establishment, what it now is, a place from which many continental Italian cities might take an example.

On Thursday, September 26th, under the direction of Messrs. Platania, on the path down to the beach, the different superposed doleritic lavas of Etna were examined, and after refreshment at one of the directors' houses, we embarked on boats, which first conducted us to the remains of the Grotto delle Palumbe, where a thick stream of dolerite exhibits, for such a coarse-grained rock, very fine columnar struct[illegible]

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energetic rowing of the fishermen took us rapidly along the coast, where very ancient Etnean basalts are intricately interwoven with Pliocene clays; where lava-stream succeeds lava-stream; where the fig-cactus and the vine monopolize every metre of loose scoria or lapillo; and where at some points fine ferruginous springs gush out from the cliff-face.

On our landing at Trezza, the largest of the Cyclopean islands, Prof. Silvestri pointed out that it was in part composed of clay metamorphosed by the contact of the basalt forming the other part of the island. The members were able to observe numerous minute dykes extending into the clay from the main mass, and to collect some very creditable crystals of analcime from the basalt. This mineral has been subsequently introduced into the basalt in such great quantities as in some cases to convert it into a rock which has been called analcimite. Landing at Acicastello, the celebrated globular basalts, with their associated palagonite tuffs, containing herschelite, phillipsite, and other zeolites in abundance, furnished ample scope for observation and discussion by the party. A comparatively recent but non-historic lava-stream is seen at one point covering some of these more ancient Etnean productions. Before taking the train to Catania, a fine fan-shaped group of basalt columns was examined close to the station.

On Friday, September 27th, invited and conducted by Prof. Silvestri, the fine museum of the University was visited by the party. This collection, probably the finest vulcanological collection that exists, and especially the beautiful models of recent eruptions of Etna, and the collection of their ejectamenta, were much admired. Not less valuable are the fine series of rough rock-specimens, with their polished equivalents and large very thin sections from the same. The Sicilian sulphurs, ambers, and other minerals add to the beauty of the collection. The museum also contains a fine series of seismological instruments. The whole represents many years of toil on the part of Prof. Silvestri.

In the afternoon we drove to Biancavilla, noticing the numerous large lava-streams cut by the road, chiefly outflows of 1669. At Paterno, the so-called mud-volcanoes, or "Salse," were examined, which, although now comparatively inactive, in 1879 showed great activity. Here Prof. Silvestri gave a discourse on the phenomena of mud-volcanoes in general, which he illustrated by those in the midst of which we were

standing. He then conducted us to the neighbouring Acqua Grassa, which is seen to be two rectangular basins, containing about two cubic metres each of a ferruginous water in a constant state of ebullition from the escape of carbon-dioxide, constituting a splendid drinking water, of which most of us availed ourselves with gusto.

It was nearly dark when we arrived at Biancavilla, having made another stop to collect specimens of the augite-andesite at the foot of the cone of Mt. Calvario. At Biancavilla we had been kindly offered hospitality in the country-house of the Marquis di Favara, a most valuable help to us, for which the party were most grateful, as there is nothing approaching an hotel in the place. Soon after our arrival the Syndic, some of the municipal councillors, and the town band came to greet us, the latter playing to us whilst dining.

At daybreak the following morning we were up, and the large quadrangular court-yard presented a picturesque scene—with over twenty mules, many recalcitrant, lethargic muleteers, excited geologists, odd-looking baggage, with the writer running here and there, directing, scolding, hurrying, urging, and otherwise stimulating the guides and mule-drivers.

Notwithstanding that the starting had been ordered for five a.m., it was nearly six before we were all fairly on our journey. A splendid morning, Etna, standing out in all its grandeur, was a picture that few who saw it will not have indelibly engraved on their memory. Not less impressive were the numerous wild, rugged lava-streams that were crossed, alternating with vines and woodland, with here and there a gigantic parasitic cone. Thus we continued till near midday, when we halted at the cones of Grotta degli Archi to eat our well-earned lunch, which was followed by a demonstration from Prof. Silvestri of the way in which these cones were formed along a lateral fissure, now known as the Grotta degli Archi, or Grotto of Arches, a tunnel the upper portion of which we entered, representing the upper extremity of the now empty dyke, and forming an arched communication from one parasitic crater to the other.

Another few hours of climbing on our mules brought us past the eruptive fissure of 1879 to the edge of the Piano del Lago, beyond which all is desert. At about 5 p.m. we reached the

Observatory, and, depositing our mules and baggage, I called upon those near by to follow me if they wished to see the crater that evening, as we did not know what weather we should have on the morrow. Six or seven besides myself started, and although I did not know the new path since the last eruption, fortune favoured us, and in spite of a strong and biting wind we were able to obtain a fine view of the crater and circle round more than half its circumference, which is probably more than a mile. It is now in a solfataric state, with nearly perpendicular walls and flat floor, probably some 100 to 200 metres beneath the rim. We descended opposite the Observatory, and had an amusing scramble over a very steep slope of hot, fuming, compacted dust.

Unfortunately, after a terrible night of piercing wind and driving cloud, the following morning rendered the ascent that was to be made under Prof. Silvestri's direction impossible, and some of the party had to descend disappointed. It is not the crater of Etna, however, that is the great centre of interest, but the innumerable things that one observes in the ascent and descent. After leaving the Piano del Lago on our way down, we quitted the clouds which were simply capping the mountain, and on our path to the Casa del Bosco, where we lunched, we often had bright sunshine. At the Observatory, thanks to the kindness of Prof. Silvestri, we had been most hospitably fed, and even at this point we had again to fall back on the abundant supply of provisions that he had provided for us.

Our next goal was the eruptive focus of 1886. We struck out of the main path for Mt. Gemellaro, a very large parasitic cone thrown up during that outburst. A considerable number of the bombs, containing partially fused quartz, thrown out on the flanks of the cone, were collected, and after photographing some peculiar lava formations, we continued our way down amidst a slight rain which rapidly increased, so that we had to hurry past the foot of Mte. Rossi without stopping to examine it. At Nicolosi we were met by carriages which conveyed us to Catania. The next day we took train to Messina, crossed to Reggio, and then went for twenty-four hours by train to Naples. The latter part of the journey, though undoubtedly fatiguing, was of great interest on account of the physiognomy of the country, from which many interesting lessons of

mountain and valley formation as well as of simple denudation could be learned.

On October 1st, the second group of the party, who had assembled in Naples, visited the National Museum, the churches of S. Chiara, Duomo, etc., Dr. A. Sambon, who especially occupies himself with mediæval art, acting as director, and in the evening they were joined at Parker's Hotel by the section from Sicily.

The following morning (Tuesday) a couple of hours were passed in examining the Zoological Station, its well-fitted laboratories and scientifically and artistically arranged aquaria, under the able guidance of the vice-director, Dr. Eisig, and MM. Linden and Megazini. We then proceeded in carriages to Camaldoli, where a magnificent view of the Campi Phlegræi is obtained. After lunch, the writer said he had brought them there to point out the general configuration of the country to be visited during the next fortnight. On the one hand was the Gulf of Naples, with its south-west side bounded by the Cretaceous and Jurassic Limestones of Capri and the Sorrentine peninsula, while at its deepest concavity rose in elegant, sweeping curves, broken by jagged precipices, the pile of Somma and Vesuvius. Then came the true Phlegræan Fields, including the amphitheatre of Naples, the ridge and Cape of Posilippo, Nisida, the hills of Mte. Dolce and Mte. Olibano, La Starza with Pozzuoli, Mte. Nuovo, the Lucrine lake, Baths of Nero, Baiæ, Bacoli, Mare Morte and Misenum on the mainland, but also the geological prolongations of the Islands of Procida, Vivara, and Ischia. The latter islands formed the south boundary of the Gulf of Gaëta, with Monte di Procida, Fusaro, Cuma, and then that long sweep of low ground of Castel Volturno, Mondragone broken only by the limestone bosses of Mte. Massico, until close to Gaëta, which is backed by the calcareous pile forming the north boundary of the gulf. The numerous cones and craters at our feet in all stages of ruin; the plains of Bagnoli, Soccava, Pianura, Quarto, in part due to old craters of explosion; later submarine bottoms when the waves lapped the foot of Mte. Barbaro and the base of the precipices we were then looking down from; the bright sun, the blue sea, and green foliage after the first autumn rains, combined, with the fantastic configuration of the country and its varicoloured rocks, to form a picture unique in itself and of

uncommon beauty. In fact, all the party admitted that they could hardly decide which impressed them most: the valuable geological lessons to be learnt from the district, or the beautiful outline and colouring of the landscape. Regaining our carriages we directed our course to the new quarter of Naples, now being constructed on the Vomero hill, where some good sections are exposed. The great mass of almost uniform yellow tuff cut into for some 25 metres is well seen overlaid by numerous comparatively recent, though pre-historic, trachytic pumice and dust beds, on which the writer expressed the opinion that they were derived from the craters of Astroni, Fondo di Ciglio, and the Fossa Lupara. He also pointed out nuclei of greener tuff passing into the characteristic yellow variety towards the surfaces of cracks and fissures, due to higher oxidation. The museum of San Martino was closed, but by the kindness of the Conservator, by order of the Minister of Public Instruction, a short round was permitted. From two of the balconies the topographical features of Naples, Somma-Vesuvius, and the Sorrentine peninsula were explained more fully than at Camaldoli.

That evening it had been intended that I should give a lecture on the geology of the Neapolitan district, and I had commenced to carry that determination into effect, but was prevented from continuing by an increase of ill-health that I had been battling with for a fortnight, and the following day I was compelled to remain in my bed. Fortunately, Prof. Bassani kindly replaced me, and under his care the party were conducted to the celebrated Grotta del Cane and the neighbouring thermo-mineral springs of the Lago d'Agnano, with the fumeroles of the Stufe di San Germano. From thence they proceeded to the Solfatara, where Prof. Bassani explained the phenomena of this semi-extinct volcano, how its emanations attack the trachytic tuffs, decomposing them into kaolin, free silica, alumina, and sulphates of the bases, which the party collected in the form of halotrichite, coquimbite, voltaïte, copiapite, gypsum, etc. Lastly, the party examined the renowned so-called Temple of Serapis, where the phenomena of oscillation of the land-level are fully demonstrated.

Sufficiently recovered from my indisposition, it again fell to my lot to grasp the guiding reins, so that on October 4th (Friday) the Campi Phlegreai was our goal.

Approaching Monte Barbaro from Pozzuoli, I drew the attention of the party to the irregular and ruined appearance of the south side of the mountain which extended round and had made so much progress as to leave a breach in the east side of the great crater, so separating, on this side, Monte Corvara, which constitutes the north side of the cone, and the crater of Campiglione, from Monte Barbaro which forms the south side. Towards the west the crater is also in part breached beneath S. Angelo, but not to such an extent; yet it is sufficient to mark the separation of Monte Corvara and of Monte Barbaro on the opposite side of the crater. It was by this former breach that we obtained admission to the great crater of Campiglione, the plain at the bottom of which is now covered by fields and gardens. This erosion of the front and sides of Monte Barbaro took place when the land-level was very much lower, so that the waves had in part destroyed this, the largest cone of the Campi Phlegræi. The deposits at the sea-bottom constitute the materials now forming the plains through which have risen, at a later date, the volcanoes visible from a point we had gained on the south-east limb of Mte. Corvara, namely: Astroni, Cigliano, Senga di Campania, Mte. Olibano, Solfatara, Mte. Nuovo, etc.

The old coast-line at the epoch when the waves lapped the base of Mte. Barbaro, and when the sea-level was some 60m. higher than at present, was as follows: Starting from the Island of Nisida it swept round the toe of the Posilippo ridge to Fuorigrotta, cutting back the cliffs behind Soccava, and beneath Camaldoli, thence to Pianura, and by a less distinct coast-line until we again meet a well-marked cliff which some distance to the west is traversed by a cutting for the road to Qualiano. The coast-line makes a sweeping loop to the south round three quarters of the Campiglione volcano, and probably including the upper rim of the Avernus and Lucrine Lakes. Monte di Procida, and a few other points of the Baja peninsula, were then islands, as well as such rocks as that on which Pozzuoli was built, Mte. Dolce, near Bagnoli, and probably Mte. Spina and some old trachyte and tuff bosses in part sheared by the eruption of Astroni on its east side. These latter eminences seem to have acted as breakwaters, and in consequence we find the old coast-line behind them more prominent and possessed of less abrupt declivities; that is that portion

from Pianura westward to a point just north of Segna di Campania.

After having examined the conformation of the Campiglione crater, we returned to the exit, near which was a quarry of the yellow tuff which composes the main mass of the cone. Numerous large fragments of grey pumice stone, quite fresh in the interior, but decomposed on the surface to a kind of palagonitic matter, illustrated how the whole of the smaller pieces and dust had undergone a similar change, blending the heap of incoherent fragments into one compact mass. This enormous collection of pumice indicated a gigantic explosive eruption which had not only built up the present cone, but probably had afforded much of the compact yellow tuff of the region, the position of which would indicate that the Campiglione volcano was later than the centre or centres from which was derived the grey pipernoid tuff of the Campanias, the piperno and the museum breccia of Pianura, Soccava and Naples.

The party then proceeded to Mte. Nuovo and ascended to the summit of the mountain, which was built up in the course of some forty hours by the constant ejection of pumice and other materials from an eruptive axis passing through the streets of Tripergola, a village with thermomineral baths on the seashore. The geologists might perceive that the main mass of the mountain was composed of a trachytic pumice, over which was spread a mantle of great masses of a dark, very basic trachyte (sometimes considered a phonolite), occasionally compact, but more often scoriaceous. This, I said, I considered to prove that while the magma in the upper part of the chimney was saturated with dissolved water, that lower down, and farther from aquiferous rocks, was less so, and had the eruption become permanent, no doubt lava would have poured out continuously. Many of those present collected fossiliferous concretions, which are similar to those found in the submarine marly tuff of Ischia, and in the submarine tuffs of the Starza which underlie Mte. Nuovo, and which are the deposits of the epoch of the erosion of Mte. Barbaro. Descending to some pozzuolana quarries, I pointed out that when we cut into the mountain for a few yards, we could see that the pumice and pozzuolana had already been converted into a yellow tuff much like that of Mte. Barbaro, although only 250 years had passed since its ejection as new material.

The crater lake of Avernus and the Lucrine lake were next visited, and the return journey included an examination of the Starza cliff, where a large collection of fossils was bagged. The following explanation was given: The materials here seen in section were derived from different sources, and in part by marine erosion of Mte. Barbaro, and were deposited at the sea-bottom when that erosion was progressing as described above. Immediately previous to the historic period, and after the rising of the land some 60m., a marine terrace was cut in these deposits with a cliff face from 10 to 100m. nearer the beach than at present. The Romans built along near the edge of this cliff, and on the foreshore at its foot (Temples of Serapis, Nymphs, and Neptune), and during this period depression was going on, the temples of the Nymphs and Neptune were probably abandoned, and a new and higher floor was added to that of Serapis. Up to the middle ages this depression continued, until the sea once more had covered the foreshore and cut back the Starza cliff to its present position, exposing and undermining the foundations of the Roman villas above. Part of these fell, were broken and rounded by the sea, and converted into pebbles. The exposed beach, with black sand, shells and brick and marble pebbles, was shown to the party, opposite the main gate to the Armstrong Works, at a height of 3·75m. above present mean sea-level.

In the evening the party paid a visit to my house to examine my private collection of rocks and minerals from the South Italian volcanoes, the former being by far the most extensive and choice either public or private, and the latter the finest private collection, or second only to that at the University, and therefore likely to prove of considerable interest to geologists visiting the neighbourhood.

The following day (Saturday, October 5) the party proceeded in carriages to the Vesuvian Observatory, and thence on foot to the Atrio. During the ascent the lavas of 1631, 1767, 1858, and 1872 were examined. The scoriaceous lava surface, with its bombs and the pahoehoe or corded type, with but few bombs, were pointed out, and explanations of the reasons of this were given. In the Atrio the dykes, lava-streams, and conglomerates were examined, and the condensation and agglomeration of the latter into a solid rock towards the lower part and centre of the great escarpment were shown to result

from heat and pressure. The newly-discovered hollow dykes and those that had been drained out and refilled a second, and even a third time, excited much interest.

The barren, rugged, and jagged lava-fields of the Atrio, the stupendous precipice, the frowning cone of Vesuvius, with its jets of stones and volumes of vapour, the latter mingling with the storm-clouds scudding through the ravines and around the towering peaks, strongly impressed those present with their grandeur.

With a basket or two of lapillo, a model was improvised to illustrate the causes of the configuration of this volcano at different periods of its growth. Some of the party descended by the Cupa Pallarino (once called the Riva di Quaglia), where the pumice beds of Somma are well seen, and where a good selection of the various ejected blocks can be collected.

The Sunday (October 6th) was occupied amongst the beauties of the National Museum, Dr. A. Sambon's demonstrations being very interesting and valuable.

Attention was drawn by myself to the various stones used in the arts there represented, as well as to the different minerals formed by the decomposition of the bronze antiquities. In the afternoon about half the members accompanied me to the tunnel of the Mte. Santo-Vomero funicular Railway in Naples, where the newly-discovered sections of interest are to be seen. A rich collection was made of rocks from the "museum" breccia as well as of the grey pipernoïd tuff. The details of this section have been described in the 'British Association Reports' (Vesuvian Committee) during the last three years. In the evening, boxes at the Bellini Theatre had been offered the party by the municipality of Naples, and a pleasant distraction from vulcanological work was found by the excursionists in Gluck's charming opera of "Orfeo."

On Monday (October 7th) the triple crater ring of the Fossa Lupara or Senga di Campana was visited, but the height and denseness of the vegetation prevented a good general view being obtained. Subsequently the sections of Pianura and Soccavo were examined. The problem of the "piperno" was broached by me somewhat in these words. Those of the party who had seen the tunnel section on the previous day would recognize its similarity to that before us. The massive yellow tuff, beneath which comes, in both cases, the "museum"

breccia, reposes, in its turn, at Naples on pipernoid tuff, and at Pianura on piperno, and these respective materials on white pumice beds. This showed that the grey pipernoid tuff and the piperno were stratigraphical equivalents. The former had all the characters of a tuff, the latter those of a lava, as indicated by flow-structure around the numerous fragments of greenish-yellow tuff, etc., caught up, by the overlying fragments of a more vitreous variety of the same, and by the presence of two (especially at Soccavo) distinct flows separated by a breccia of trachytic rock-fragments. Some authorities had supposed the piperno to be a metamorphosed tuff, but an examination of the section disproved that view, since the underlying pumice was unaltered, as also the trachytic breccia between the two flows of piperno. These facts lead us to the conclusion that not far from here, and probably a little to the south of Soccavo, at one time stood the great piperno volcano, subsequently destroyed by explosive eruptions and marine erosion, and that this was the centre from which was dispersed the grey tuff of Naples and of the whole Campania, which is of the same age. As regards the origin of the pipernoid structure, it could be explained by supposing the vent opening at the top of a fissure filled by the original magma, at the junction of two portions which contained different proportions of dissolved water and had undergone different stages of crystallization from cooling. The pasty magma would then issue with a laminated structure, just as different coloured clays or soaps do through a narrow aperture, the greater cohesion of the black, more vitreous, and less cooled portion causing the separation of the laminæ into larger pieces, which, with their peculiar, crushed, and squeezed-out surface, have remained in the lighter coloured, more granular, crystalline, less cohesive, and cooler groundmass, which from containing more water tended to its disintegration to dust.

On Tuesday (October 8th) the train was taken to Pompeii, where Dr. A. Sambon acted as archæological director, and the beauty of the buried city being duly admired, the attention of the party was turned to the materials in which the town was buried. The pumice, with the more vitreous lower part, contains, as porphyritic inclusions, crystals, chiefly of intratelluric minerals; whilst the upper part, darker in colour and more microcrystalline, has inclusions of crystals of post-eruptive

minerals, and above these pumices come the pisolitic dust-beds. These are followed by very thin lapilli beds of later eruptions. The leucitic lavas on which the town stands, and the different rocks used in the arts by the ancient inhabitants, also attracted attention.

Signor Dini had kindly placed his steam-tug at the disposal of the party to visit the quarries of 1631 lava owned by him, which are the largest and best worked on the mountain. The rough sea and unfavourable weather prevented our availing ourselves of that kindness, and also of refreshments it had been the intention of the proprietor to offer us. After visiting Pompeii, we drove over to one of the smaller quarries of the 1631 lava, where the irregular columnar structure, shearing-planes, steam-caverns, and scoriaceous surface with bombs, could be well seen in section.

Early the next morning, being joined by Professor Bassani, we drove to the quarries of Faiano, near Nocera, where the grey pipernoid tuff is seen and quarried to 20 metres in depth. I explained that these tuffs are found all over the Campanian plain and a great part of the Terra di Lavora, almost uniform in structure. Where they are in close vicinity to high limestone mountains they contain fragments of that rock, which are more or less, according to size, converted into silicates and fluorides, which was supposed to be due to the action of hydrofluosilicic acid, which probably formed one of the soluble constituents of the dust as it fell. What was of great interest was the fine crystals of biotite and nepheline, besides pyroxene and amphibole. Of not less important bearing on the temperature and pressure of metamorphism was a deer bone, which I lately found there, covered with amphibole and some nepheline crystals, but still retaining traces of animal matter. The age of this grey tuff is indicated by its stratigraphical position, which, taking distance into consideration, is similar to that of the grey pipernoid tuff of Naples and the piperno of Pianura. At Fiano and the neighbouring Fossa Lupara (not that north of Astroni) the grey tuff is overlaid by the Somma pumices representing the eruptions that excavated the Atrio del Cavallo crater (PHASE III TO VIII). In the great Atrio section, we have exposed the different mantles of volcanic ejectamenta, the lowest of which date back to the time when the entire cone of Somma could not have been as high as the present Vesuvius;

yet no traces of it are to be found, so that it must be more ancient.

Rejoining our carriages, we drove along the Sarno plain, at the foot of the limestone mountains to Castellamare, Professor Bassani pointing out the characters of the sedimentary rocks. After dinner, Professor Bassani gave a very able and interesting discourse on the orography of the Sorrentine peninsula and Capri, together with an account of the recent geological investigations of that district.

On the following morning (Thursday, October 10th), under the joint direction of Professor Bassani and myself, the sections exposed along the road from Castellamare to Sorrento were examined. We descended from the carriages at different points to visit the fine exposures of the Neocomian ichthyolitic limestones and the Orbitulina-marls (Aptien), ably guided by Professor Bassani.

Just before Vico Equense, we descended to the bathing establishment, where nearly at sea-level a very abundant spring of a very rich sulphur water issues, and the products of oxidation of its sulphur-compounds erode the limestone into fantastic caves, from the fissures of which abundant crusts and crystals of selenite, as well as some epsomite, can be collected. Close at hand I drew attention to a patch of the grey pipernoid tuff, with pieces of limestone partly converted into fluorides, etc. This tuff is seen reposing on some much older volcanic deposits, yellow earth and pumice collected in depressions in the limestone.

On our arrival at that point of the road which overlies the plain of Sorrento, I explained the structure as follows: the Sorrento peninsula represents an upthrow along a line of fault marked by its southern coast. Springing from this main fault, nearly at right angles, extend a number of transverse ones, and between two of these a depression is formed by a downthrow. This lower slope has been partly levelled by filling up with grey pipernoid tuff similar to that we saw at Nocera and Naples. This tuff is beautifully seen from our standpoint, forming a long line of cliff limiting the plateau seawards. These cliffs have a coarse columnar structure, which in other localities is often developed to great perfection, and the tuff near the contact with the limestone contains the usual inclusions.

The municipality of Naples had kindly placed a large steam-yacht, the "Sibilla," at our disposal, and on our arrival at Sorrento we were met by a deputation of representatives from the Naples municipality, consisting of Professors Majone and Roccatagliata, and Captain Vercilli, with whom we immediately embarked.

Within an hour we found ourselves at the Blue Grotto of Capri, which we were able to visit, owing to the calm sea.

On landing, our party, which was now over fifty in number, were divided amongst three hotels. After lunch, the prehistoric flint and obsidian implements, rocks, minerals, etc., of the island, carefully collected by Dr. Cerio, were exhibited by that gentleman, and the thanks of the party were offered to him with the expression of their admiration of his efforts to get together under many difficulties this valuable local collection. Later the party ascended to the Palace of Tiberius, and along the road Professor Bassani lucidly explained his own views, as well as those of Oppenheim and others, on the relationship of the Jurassic and Cretaceous rocks of Capri to those of the Sorrentine peninsula, and other parts of the mainland. From the ruins of the Palace of Tiberius the magnificent view at sundown, and the historic reminiscences called up by the locality, and ably recorded by the Rev. J. C. Fletcher, of Naples, deeply impressed everyone. After dinner, the party accepted coffee, etc., offered by the Mayor of Capri, and walked over to the Villa Tragara, the property of C. W. L. Ostermoor, Esq., of London, from which a magnificent moonlight view of the island was obtained, and where a pleasant hour was spent in admiring the scene, and consuming the liberal supply of refreshments provided by Mr. Ostermoor.

The next morning, October 11th, found us betimes on board the yacht, and a pleasant steam of two hours brought us to Casamicciola in the Island of Ischia. I had requested the captain to take the course outside Procida, so that those on board might admire the remarkably picturesque situation and surroundings of the town of Procida, and look into the partially submarine crater of Vivara Island. On landing at Casamicciola, the town authorities met us, and placed carriages at our disposal, with which we proceeded to visit some parts of the island. Monte Rotaro crater with the Monte Tabor lava-stream of mellilite trachyte, the craters of Montagnone, Porto d'Ischia,

the trachyte dome of Castello d'Ischia, and the bosses of ancient trachyte were pointed out. The road we followed lay for some distance over the olivine-trachyte lava-stream, the rough surface of which is still well seen, although at many parts small pine copses have been planted. Passing close to the irregular crater ring of Cremate, I pointed this out as the source from which this lava-stream, called the Arso, flowed in A.D. 1302 for a distance of two miles, when it entered the sea, forming a promontory. The Molara and another parasitic cone and crater were examined. At Testaccio, quitting our carriages, we descended to the beach of Maronti, but owing to the heat and the tiring walk on sand, the party did not reach the patch where the beach and sea-bottom attains a temperature of boiling water; nevertheless, some fine gorges in alluvial tuff, illustrating denudation, the formation of earth-pillars, etc., were examined. On the return of the party to Casamicciola, the remaining half-hour at our disposal was devoted to a drive round the earthquake ruins of the town. After a sumptuous dinner, at which over 50 people sat down, votes of thanks were offered to the municipalities of Naples, Capri, and Casamicciola, and their representatives. So high did the spirits of the company rise, that even ladies became eloquent and proposed toasts, which, though short, were no mean specimens of oratory.

A calm sea, a bright moon, and a soft evening, made our return trip to Naples such as is not to be forgotten. The deep indigo sea, and the trace of haze gave to the promontories, islands, and rocks a fantastic beauty, whilst the majestic, sweeping curves of Vesuvius, crowned by the jewel-like volcanic fires and vapour plume, reminded us that amidst all this beauty beneath and around us, the great igneous forces of nature were but in a recuperative slumber, a slumber the awakening from which will be earthquakes and eruptions.

The crater of Vesuvius, the principal focus of the volcanic activity of the Naples district, was the centre of the hopes and wishes of the party. I had placed it at the beginning of the programme, but for ten whole days either strong wind or cloud cap had prevented me from making the excursion. Over sixty visits to the Vesuvian crater had taught me to be cautious, but some members of the party, inexperienced of the locality and impatient to get there, openly rebelled and went on their own

account, of course failing to see anything more than mist. Saturday morning, 12th October, being more favourable, I gave the order for Vesuvius. Fortune favoured us in every way, and even a little cloud that had collected on the mountain top dispersed before our arrival. Four concentric crater-rings were visible, and at the bottom of the central one, two vents which all the party were able to approach within twenty yards, were giving issue to high-pressure vapour and pasty lava-fragments. Descending some 100 metres on the east side of the great cone, we were able to approach a small stream of lava, upon which various experiments were performed.

Sunday, October 13th, was a well-earned day of rest, and, although, owing to the loss of two days, the excursion to Monte Somma should have been undertaken, yet the majority of the party prayed for rest, and none desired it more than myself, still imperfectly recovered from my indisposition.

One or two of the youngest members of the party, however, had a successful trip to the locality. Neither on Monday could all the attractions of the Mineralogical Museum of the University, or the extensive knowledge of its contents of the venerable Professor, A. Scacchi, infuse sufficient stimulus in the flagging energy of the party. Packing the numerous spoils of the vulcanological chase required a considerable share of the morning.

Starting by the 3.25 express train, we arrived at Sparanise just before sundown, and were met by carriages placed at our disposal by the Province of Terra di Lavoro, to convey us to the town of Sessa Aurunca, where we arrived some time after dark. As the town possesses no hotel, the municipality had kindly allowed us to sleep in the Lyceum, the scholars being sent to their homes or friends' houses. The married couples were placed in different private houses. In the hall dedicated to the celebrated Nifo, a native of Sessa, a luxurious banquet was offered us by the town, most of the municipal authorities being present at the table.

The following morning (Tuesday, October 15th), after coffee offered by the municipality, we mounted in carriages, again provided by the province, personally represented by Prof. Spatuzzi. It was fortunately market day, and what the ordinary visitor, who follows the regular travellers' track, does not see, was a most interesting spectacle to our party. As we

wended our way up the vine and olive-clad slopes of the extinct volcanic pile of Roccamonfina, the yellow tuffs, then the leucotephrite and leucitite lavas and breccia beds, were of great interest. The peculiar decomposition of the former rock into a kind of concentric lamellar wacke, which often completely involved a stream, and made it look like a tuff, taught an important lesson to those who had studied ancient volcanic rocks. Near the entrance to the great crater-ring the explosive pumices and lapilli, near a great leucitite dyke composed of large leucite crystals in a fine-grained base, are well seen in the road-section. A little beyond, overlying all other deposits, we have the grey pipernoid tuff in columns that we had studied at Naples, Faiano, Vico and Sorrento. The town of Roccamonfina is the birth-place of the Com. N. Amore, the Mayor of Naples, who had done so much for us during our stay there, and he had determined that we should be equally well received in the town of his boyhood. On nearing Roccamonfina, we were met by the Mayor, Town Council, and the other notabilities of the place, including Com. Amore's brother. We had to descend from our carriages and enter the town in state procession, preceded by a town band, and amidst the shouts of welcome from all the inhabitants, who had turned out to see "gli scienziati Inglesi."

While lunch was being prepared, we ascended to the Pietritroccoli, one of the central eminences of the mountain. From this favourable position I made the following observations:—"You will notice the striking similarity in size and configuration of this volcano to that of Somma-Vesuvius. This similarity even extends to the leucitic rocks forming the main mass of the mountain. Some years since I spent some weeks in studying this volcano, but have never published the observations then made. Doctor Bucca and Signor P. Moderni, both of the Italian Geological Survey, have since then published short memoirs on the mountain. The researches of the former are chiefly petrographical, and his views quite correspond with my own; and Signor Moderni has added much to our knowledge of the sequence of the different eruptive products, especially the lavas, and I propose to supplement those researches by alluding to the information to be derived from my own observations.

"So far as we know, the volcano originally consisted of a gigantic cone, built up by the constant outpouring of lavas and

the ejection of scoria, lapillo, and dust. These materials were both characterized by the presence of leucite, and, according to the researches of Bucca and Moderni, the earlier outpours are of leucitite and the second of leucotephrite. My own observations lead me rather to consider them as intermitting with one another, and also to conclude that during the leucitite phase explosive eruptions occurred with the production of much white and grey pumice, pumiceous scoria, etc. As the great mountain grew, parasitic cones burst forth from its flanks, from which flowed the leucitic lavas, and Signor Moderni enumerates no less than a dozen such, still recognizable. The main volcanic cone having attained an altitude of from 2,000 to 2,500 m., one or more violent explosive eruptions truncated this cone down to less than 1,000 m. in height, leaving a large crater-cavity from five to seven kilometres in diameter. This or these explosive eruptions were around an axis a short distance to the east of the old one, upon which had been built up the old cone during long periods of Vesuvian activity. The products of this or these explosive eruptions we see in the numerous and extensive beds of white pumice and yellow tuff derived therefrom on some of the upper parts of the mountain, and especially around its toe. Around this new axis of eruption, exudation rather than eruption of an augite-andesite lava took place, building up a great triple dome or mammelon, on a portion of which we are now standing, and partly filling up the great crater-cavity. The annular fossa between this central cone was subsequently filled up level with the lower part of the great crater rim by fragmentary eruptive materials from other centres, and by erosion of the central cone and the inner crater walls. The latter are known at present as Monte La Frascara and Serra Piccola, or sometimes as Monte Cortinelli. You will recognize the analogy of this crescentic enceinte with the similar escarpment of Monte Somma, the circular plain on which the town of Roccamonfina is situated, with that of the Atrio del Cavallo and the Pedimentina, and, lastly, the compound cone of Monte S. Croce, Lattani, and Pietri-troccoli, on which we now stand, with the great cone of Vesuvius. Trachytes were poured out from thirteen lateral cones at an uncertain date, which Signor Moderni places just previous to, during, or after the production of the great central andesite mass. Then followed a period during which nine other parasitic cones gave forth basaltic

lavas, scoria, etc. Two of these latter had formed on the crater plain, constituting the hills of Tori Sichi and Garofali.

"At a still later date enormous quantities of a fine dust were deposited on the volcano from some distant source, which, when washed down, choked the valley by the resulting tuff, which often exhibits beautiful columnar structure, and if not identical with, bears a very close relationship to, the grey pipernoid tuff of the Campania."

Descending to the Town Hall, we found a plentiful lunch awaiting us, provided at the expense of the Commune, to which we did full justice after our long walk and climb. After taking coffee at the house of Cav. Amore, we again resumed our carriages, and drove down to Mignano. Although rain was now falling, we stopped at various points along the road, and at one spot made a good bag of large leucite crystals. At Mignano station we took the Roman express, it having been stopped for us by order of the Minister of Post and Telegraphs. We descended at the station of Cassino, and had over an hour's drive in torrents of rain to the top of Monte Cassino, where we were most cordially received by the prior, Dom Oderisio Piscicelli. One carriage had broken down on the way, and the occupants had had to tramp the rest on foot, one gentleman being only shod in thin slippers. A luxurious dinner, served in the great hall of the monastery, soon restored our drooping spirits and exhausted energies, and after a pleasant chat with the prior and other monks we retired to our comfortable cells, and slept a blessed, and, I hope, a saintly, though certainly profound sleep. The ladies had been quartered at the Foresteria, outside the monastery, and were equally well treated.

The next morning they were allowed to join us, and visit this remarkable centre of culture, with its valuable works of art, archives, antiquities, natural-history specimens, etc. The reproduction in lithography of the designs of ancient ecclesiastical robes and the printing and publishing of the contents of the innumerable manuscripts were all duly appreciated.

Lunch was served in another apartment, where ladies could be admitted, and the honours of the table were taken by the Rev. Prof. Laitine, a French monk specially delegated to receive strangers. After expressing our gratitude to the prior

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Lunch was served in another apartment, where ladies could be admitted, and the honours of the table were taken by the Rev. Prof. Laitine, a French monk specially delegated to receive strangers. After expressing our gratitude to the prior

and all the fathers of Monte Cassino, we commenced our descent on foot. Prof. Bassani, of Naples, who was to have directed, being unable to be present, had kindly handed me the following notes, which I communicated to the members:—

Monte Cassino is entirely composed of Cretaceous rocks containing *Hippurites*. The rock is a compact limestone, sometimes arenaceous, of a dirty white, dark yellow, or carnation colour. It is always traversed by veins of crystalline calcite, and often resembles that of Castellamare. The stratification is rarely clearly defined, but may be well seen at the commencement of the road from the town to the monastery. Three quarries occur in the neighbourhood, one just north and to the right of the station; another north of the town, and at the base of Monte Silvestro, beneath and to the north of Castello Manfredo (Rocca Jovina). The strata dip in the former 30° towards north, 40° west; and in the second, 42° towards north, 40° west. The third quarry is the most interesting, because one can easily collect specimens of *Hippurites* from it. It also exhibits a calcareous breccia. It is situated a few paces from the carriage road to the monastery, about twenty minutes' walk up.

A considerable number of specimens were collected, amongst which were some crystals of sulphur, which I discovered in a geode, its first known occurrence, I believe, in these Cretaceous rocks. Again joining the express train to Rome, we arrived at that city late in the evening, and took up our quarters in the Via Sistina, in the pension of Mrs. Dawes.

The following day (Saturday, October 19th) being wet, we visited the Museum of Geology and Mineralogy of the University, under the valuable guidance of Professors Strüver, Portis, Clerici, Tellini, Bucca, etc. The interesting series of minerals from the ejected blocks of the Lazial and Sabatine volcanoes, and the collection of decorative marbles and porphyrites used by the ancient Romans, were much admired.

Later in the day we examined the Museum of Geology and Agronomy at the "Istituto Geologico," in Via Susanna, under the able guidance of Cav. Ing. Zezi, the secretary to the Comitato Geologico (Geological Survey). The great variety of Carrara and other Italian marbles, the collection of building-stones and rocks, were duly admired. The interesting models of the Lipari Islands, Ischia, etc., were of great interest, and I

took this opportunity to draw the attention of those members who had lately visited the Aeolian Islands to their subaërial and also to their submarine conformation, pointing out how Stromboli is a very large and high volcano, half of it being submarine, and the origin of its Sciarra del Fuoco. Similar to Stromboli, Filicuri and Alicuri are seen to be composed of one or more semi-submarine cones, whilst Lipari is an exceedingly complex association of basic and acid volcanoes. The structure and physiognomy of Vulcano could be well studied on the raised model.

The next day (October 20th) being Sunday, the forenoon was devoted to St. John-in-Lateran and St. Peter's, and after lunch a number of other churches were visited.

On Monday, in carriages, we proceeded to the Capo di Bove, Signori Zezi and De Marchi acting as directors. In the quarries opened in the great lava-stream nearest to Rome, which flowed from the great Lazial volcano, some very fair specimens of nepheline were secured. The pozzuolana quarries, newly opened, close to the tomb of Cecilia Metella, were entered, and numerous good leucite crystals were collected. The Via Appia, the Catacombs of St. Calixtus, and the Circus of Maxentius were visited, in which latter the inner man was refreshed by a picnic lunch. In the afternoon the so-called pozzuolana quarries of the Tre Fontane were examined and a visit paid to the monastery and Eucalyptus plantations of the Certosa. On the return journey a stoppage was made at the magnificent church of St. Paul without the walls.

On Tuesday, October 22nd, we took the early train to Frascati, observing the peculiar facies of the Campagna Romana on our way. At Frascati, having provided the weaker of our party with donkeys, we made the ascent of Monte Tusculo, Signor Zezi and Prof. Portis acting as directors. The rock, supposed by the local geologists to be a lava, but undoubtedly in most cases, according to my own views, an altered and compacted scoria, which is locally known as "sperrone," was seen to perfection. This rock has been very much used both by ancient and modern Romans as a building-stone, especially for posts, lintels, traves, etc. The ruins of Tusculum were finally reached, and lunch taken in the small theatre. Chestnuts were ripe, and we had filled our pockets with them: before lunch we made a fire of brushwood over them; and at the end of the meal

we had them ready roasted. From the summit of Tusculum Signor Zezi explained the configuration of the Alban Hills, and how the point on which we stood formed part of the rim of the great outer crater. The descent was made by way of Camaldoli and Monte Porzio, which latter is built on a parasitic cone, the form and structure of which can be easily studied.

Wednesday (October 23rd) was devoted to studying the rocks upon which the Eternal city is built, under the direction of Prof. Portis and Signor Clerici. At the Valle dell'Inferno, the directors drew attention to the fine section, in which three distinct beds were visible. The lowest, of bluish-grey sandy and fossiliferous clay, was the Pliocene marine clay; superposed on this we have the second stratum of yellow colour, composed of beds of sand which are also fossiliferous and of Pliocene age; and, lastly, the third or uppermost cap was of a darker yellow tint and consisted of materials of volcanic origin derived from the neighbouring volcanoes. Being specially permitted to enter the Farnesina, we descended to a brickyard, near which was a very fine section, similar to the last, and from which a rich selection of fossils was made. Here Sig. Clerici, who has devoted much time to the study of this formation, gave many interesting details.

On Thursday (October 24th), under the direction of Prof. Meli, we proceeded in train to Frascati, and from thence in carriages to Rocca di Papa, which is situated on the edge of the inner great crater-ring, often stopping to examine and collect. After an "al fresco" lunch, we ascended on foot to Monte Cavo, much of the way being over the polygonally paved road, made by the Romans, still in splendid repair. The constant occurrence of V. N. (Via Numinis) referred to the temple to Jupiter Latium which once occupied the summit, the centre of the annual pilgrimages of the Latin races who camped in the subjacent crater-plain. Monte Cavo is a small cone thrown up on the edge of the inner crater-ring which encloses the crater-plain just mentioned, which is known as "Campo di Annibale," although Hannibal never encamped here. Prof. Meli referred to a passage in Livy, which mentioned the occurrence of a rain of stones on the Alban Hills, supposed to be due to some eruption close by. The descent was made by way of the Madonna del Tufo, to Albano, where we passed the night at the Hotel de l'Europe. At dinner Mr.

T. V. Holmes, F.G.S., the President of our Association, said that he regretted having to leave us on the following day, and took that opportunity, in the name of the Geologists' Association and Geological Society of London, to thank Dr. Johnston-Lavis, and also Mr. L. Sambon, who had done so much to make this scientific excursion a success. He had greatly enjoyed his visit to that beautiful country, of which he would carry away an indelible remembrance. He drank to the prosperity of Italy; and as her volcanic fires were not yet spent, so he hoped that neither were those gifts which once had rendered her the first nation of the world. Profs. Meli and Portis, as also Mr. L. Sambon and myself, replied.

Early the next morning (Friday, October 25th) we took carriages to Genzano, and thence on foot made the whole tour of the beautiful Lake of Nemi. The party had the valuable services of Profs. Meli and Portis, to whom were added Signori Zezi and Tellini. The character of this crater-lake was explained, as well as that of Valle Ariccia, of which we had obtained a fine view. The latter has been filled up to its lowest edge by alluvium brought down from the hills above. Many interesting specimens were collected, including many varieties of peperino. After lunch at Albano we mounted to the edge of the Albano crater-cavity, which contains a much larger crater-lake than Nemi. Numerous ejected blocks, with haüyne and other minerals of contact metamorphism were obtained. The edge of the crater was followed to beyond Castelgandolfo. Just beyond this town Prof. Meli pointed out the vegetable impressions on the under-surface of the peperino which indicated its mud-like character when ejected. Descending to Marino, the numerous and extensive peperino quarries were visited, and our bags having reached the limit of what they could contain, pockets, greatcoats, baskets, and even ladies' mantles were converted into receptacles for the numerous heavy but interesting examples of rocks and minerals, with which we returned to Rome by the evening train.

Saturday (October 26th) saw us, with Signor De Marchi at our head, taking the train to Montecelio, near which, at Collelargo, are the quarries of Messrs. Maggiorani, worked in the Liassic limestone. In one quarry we found the old Pliocene shore-line, in which the limestone is bored by *Lithodomus* and *Clionia*, and presents other similar indications. Here we lunched,

being supplied with refreshments by the proprietor, to whom a vote of thanks was accorded. Returning we examined the bathing establishment of the "Acqua Albule." This spring, which forms a small river, sufficient to be utilized for mechanical power, is very rich in carbon-dioxide and hydrogen-sulphide. The former and the oxidation-products of the latter produce very remarkable effects upon the solution and deposition of lime in the form of travertine. Next we were conducted in a special train, provided by Count Guiseppe Savorgnan di Brazza, to his quarries of travertine, where we were joined by Signor Lanciani, the Professor of Archæology in the University of Rome, who kindly gave us much valuable information of an antiquarian nature, from which we could glean the following: These were the ancient Roman quarries, from which the stone of the Colliseum, Basilica Julia, Castle of St. Angelo, and numerous other buildings was derived. They had but lately been reopened, and we were able to see a talus of travertine that had formed against the old quarry-face since Roman times. The area that had been denuded by the ancient workers was very great, as also were the mounds, or more properly hills, of *débris*. Even tombs of the ancient quarry masters had been met with. The method of cutting out and splitting off blocks of this rock, one of which was 40 c.m. in volume, was seen going on, and Mr. G. W. Butler, B.A., obtained some photographs of it. After Count S. di Brazza had liberally supplied us with tea, sandwiches and champagne to sustain us during our return journey, we entered our special carriages, which at Bagni were attached to the train to Rome.

After dinner the members of the excursion assembled in the salon of the hotel, where I gave the discourse which I had, on account of ill-health, been unable to do at Naples. The general arrangement of the Italian volcanoes and their geological age were referred to. The only rational theory that explains all the phenomena of eruption was in a few words described, and the different regions we had visited were recalled as illustrations of the theory.

Sunday, October 27th, was again given to the churches and antiquities of Rome.

On Monday, October 28th, in steam-tram, we took the road to Tivoli with Prof. Portis, Sig. Zezi and De Marchi as our leaders. We were met at Tivoli by Cav. Tomei, and taking

the ladies in his carriage he conducted us to the sights of the town. The beautiful Villa Gregoriana, the cascades, both natural and artificial, the Mesozoic limestones, and, above all, the formation, in some cases rapidly progressing, of calcareous tuff and travertine in and near the caves of Neptune and the Siren. After partaking of lunch, the different works that utilize the water-power were inspected, and on our return journey we drove through a new subterranean viaduct lit up by incandescent lamps, worked from the electric illumination station.

In the evening the members of the party issued an invitation to the directors of the different excursions, including Profs. Lanciani, Meli, Portis, Count G. Savorgnan di Brazza, Cavalieri De Marchi, Zezi, etc.

Dr. Drew, who had presided after Mr. Holmes's departure, said, in recalling the numerous and deeply interesting excursions that they had made, he could not forget the provinces and municipalities that had offered us hospitality, thus showing sympathy to us Englishmen and interest in science; still less could he forget the professors and friends who had directed and aided them in their excursion, and he wished especially to express his thanks to Dr. Johnston-Lavis and Mr. L. Sambon, who, with their wide information, their knowledge of the localities and their love for science, had known how to overcome the obstacles and carry into execution the programme that had been proposed. He was not only grateful to Dr. Johnston-Lavis for having promoted such an important series of excursions, but also for having added so much to the advancement of vulcanological science by so many years of disinterested study, with so much intelligence and so much enthusiasm.

Before finishing his speech, he felt it his duty to combat two false and preconceived ideas of English people regarding South Italy, viz., the laziness of the people and the insalubrity of the towns. Wherever he saw man, woman, or even children, they were working with great activity, and were working for little or nothing. Then at Naples and elsewhere, all had been to visit the magnificent Sanitation works, and he recalled the interesting discourses of Prof. Spatuzzi, Signor Sambon, and Dr. Johnston-Lavis, who had shown with statistical data how Naples was far healthier than many well-known European cities and that it had made an enormous stride in the last two or three years,

which brought it up to the level of sanitation which modern civilization requires. He, therefore, could not do better than wish Italy a future as glorious as her past.

Dr. Johnston-Lavis, in reply, said that he could only express his deepest thanks for the flattering remarks referring to himself and Mr. L. Sambon. He felt it an honour to have been useful to such a large body of scientific men and women.

Mr. L. Sambon said he was sure he should be interpreting the sentiments of all in expressing their gratitude to Comm. P. Boselli, the Minister of Public Instruction, who, patronizing this journey through Italy on the anniversary of the celebrated voyage of the great Spallanzani, had shown how much interest he took in science and the renown of the country.

Count G. T. di Brazza drank to the harmony of science, art, and industry, and to the friends of his country.

Prof. Lanciani drank to the health of Old England, calling her the modern Rome, for her greatness was in her colonies, as was that of ancient Rome.

Signor Ingre. Demarchi drank to the lady members of the party, who proved how strong the weak sex were in England.

Mr. G. Potter said that as one of the three founders of the Geologists' Association, he was glad to see that on its 30th anniversary he should have been able to take part in the greatest and most successful enterprise yet undertaken by it, and he, therefore, in the name of that Association drank to the health of Dr. Johnston-Lavis, to Mr. L. Sambon, and to the professors of Catania, Naples and Rome, who had directed the various excursions.

The following day the party broke up, but a considerable number remained to see the sights of Rome.

In bringing this report of our excursion to a termination, I must first ask your pardon for the imperfections in the style and details of the account, which have been due to the very limited spare time at my disposal. In a considerable number of places it has been necessary for me to speak of myself, but although I should have wished to do otherwise, it would have rendered the account so disjointed as to have made it unsatisfactory.

Altogether, it may be said that the journey was made without any serious hitches, and even where some discomfort and displeasure were caused there was ample justification for them. A journey in Italy is not the same as one in England,

nor is one that lasts nearly two months to be compared with one of a week. Such conditions as a different people, few and bad means of communication, absence of hotels, along a track where it is considered the duty to impose on the foreigner, besides the want of punctuality and absence of those business habits on which so much depends, renders the burden of responsibility a most heavy one. Had I not had the kindest co-operation of my valued and many-gifted friend, Mr. L. Sambon, I am sure that I could not have made the excursion approach to a success. I take this opportunity in offering my deep gratitude for his valuable aid, when suddenly I found myself not only holding the helm of responsibility in the vast ocean of science, but amidst the reefs and breakers of administration. Lastly, let me thank the Association for the confidence it placed in me in putting in my charge such an important undertaking, and also for the kind tolerance towards me, when troubled by ill-health, worry, want of sleep and repose and unfavourable weather, of those who took part in it. In conclusion; let me wish success to this Association, which may be looked upon as the pioneer of its kind, and hope that this may be the first of a series of excursions to localities where the grand geological processes and phenomena are easy of access. Amongst such may be mentioned the volcanic districts of Iceland, the Auvergne, the Eiffel, the Tyrol and Hungary, the glaciers, lakes, and mountain sculpture of the Alps and Norway. I am grateful for the many valuable lessons in geology I have learnt through this Association, and there is little doubt that hundreds of others are equally or still more indebted to it.

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Notes on the Curious Appearance Produced by the Natural Bisection of some Spherical Concretions in a Yoredale Sandstone Quarry.*

By W. Hind, M.D., F.R.C.S.

(Read March 7th, 1890.)

It was on a visit of the North Staffordshire Naturalists' Field Club to the Yoredale Sandstone quarry at Gun Hill, north of Leek, that the condition of things to be described was observed.

Gun Hill is the apex of a Yoredale anticlinal which runs north and south from Stalybridge to Wetley Rocks in North Staffordshire, and a line of fault runs the whole distance. This fault and the anticlinal are well exposed in the quarry, the beds dipping east at 20° and west at 45°. Gun Hill is about 1,000 feet above sea-level, and there are several minor faults and slips to be seen in the quarry.

On the east side of the quarry the beds are beautifully ripple-marked and consist of beds of sandstone varying from 10 to 20 inches thick, separated by thin beds or partings $\frac{1}{2}$ inch to 1 inch of loose shale. Here the eastern face of the quarry has been somewhat undermined, leaving the upper beds with their lower surfaces exposed. On the lower surface of one of the overhanging beds were seen twelve sets of concentric markings, varying from 9 to 15 inches in diameter (See Fig. 1); at one part its under bed had not been taken away, and a quarter section of the marking was seen lying on a shale-bed half-an-inch thick. On fully exposing this one, by removal of the lower stone, no markings were seen below. On chipping away the rock round the markings it was found that they could be removed as half spheres, the convex surface being smooth and having no intimate connection with the rock-bed. The rock and hemispheres were of a close-grained semi-crystalline quartz, and apparently both of similar condition. The concentric striæ were well marked in all, and varied in depth from $\frac{1}{16}$ to $\frac{1}{8}$ inch, and they were just as well marked in the

* The specimen exhibited has been presented by Dr. Hind to the Museum of Practical Geology.

specimen which was not fully exposed. All these bodies were within an area of five square yards.

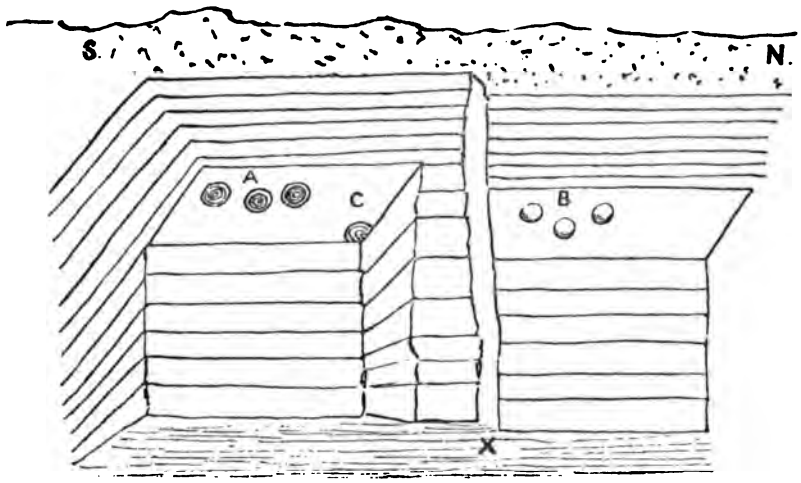


FIG. 1.—SEMI-DIAGRAMMATIC VIEW OF GUN HILL QUARRY.

A. Bisected concentrically-marked concretions. B. Hemispheres projecting from bed. C. Concentrically-marked body exposed by the Director. X. Fault.

North of this space was a fault with well-marked slickensides; the downthrow of which was small, about 1 foot, the direction being east and west; and for about one foot the rocks were broken up by the fault.

North of the fault was seen projecting from the lower surface of an overhanging ledge about one foot higher than the bed, with the concentric striæ on the other side of the fault, four spherical bodies the lower hemisphere quite developed; these could be chipped out as fairly perfect spheres. There was an absence of shale-parting, the spheres appearing to be situated in the middle of a bed of stone. They were about 9 inches in diameter; on breaking they were close grained, and gave no naked-eye evidence of concentric examination (Fig. 2).

I searched in vain on this and other occasions to find some hemispheres with the plain surface upwards, the corresponding halves of the striated ones.

On the other side of the cutting in the quarry directly opposite to the group of concentric striations there was a well-marked

surface of slickensides between two beds parallel to their dip, showing that they had slipped over one another.

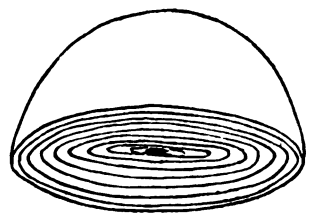


FIG. 2.—NATURALLY-BISECTED CONCRETION, SHOWING CONCENTRIC RINGS.

The workmen informed me that the finding of these bodies is uncommon.

These bodies are doubtless concretions and have been formed *in situ*, and I submit that there can be no doubt that the curious appearance of the bisected concretions lying with plain surfaces downwards is due to the fact that when the anticlinal was formed the various beds slipped over each other parallel to the bedding, giving way in places of weakness, such as is represented in this case by the half-inch parting of shale, and that doubtless the lower halves are somewhere within a few yards, with their plane surfaces upwards.

The fact which now only remains to be accounted for is what was the cause which produced the concentric grooves in some places half-an-inch deep. That it is not caused by direct exposure to the atmosphere is shown by the fact that the concretion which I exposed myself was as well striated as any of the others, although it was all but covered. The probability is that chemical action has brought about this condition of things, but looking at the composition of the concretions, what this was is not very clear. I cannot see how percolation of water along the bedding-planes would act upwards.

There is no effervescence on the addition of nitric acid, neither is there any chemical evidence of dolomitic change after prolonged action of dilute nitric acid, and on addition of molybdate of ammonia there is only the faintest change of colour, so that the material cementing the quartz grains is evidently of a siliceous nature.

The solution of the problem is probably to be found in the fact that the surfaces have been lying in a carbonaceous shale, through

which rain water has been percolating for ages, but I cannot attempt to define more certainly the *vera causa* than to guess that it probably was gaseous.

A description of this quarry and the anticlinal fault is to be found in the "Geol. Survey Memoir" 'Country round Stockport, Macclesfield, Congleton, and Leek,' by Messrs. Hull and Green, pp. 42, 43, 17, 55.

On the Manufacture of Serpentine in Nature's Laboratory.

By Major-General C. A. McMahon, F.G.S.

(Read May 2nd, 1890.)

The Members of the Association who joined in the Excursion to the Lizard in August, 1887, will recollect the large area of serpentine rock exposed to view in that district.

The interest in the subject excited by that and subsequent visits to the Lizard has led me to pay some attention to the process by which serpentine has been manufactured in the laboratory of Nature, and although I have nothing novel to offer you, a brief account of this process, and the questions involved in it, may, I trust, prove interesting to the Members of the Association.

The mineral known by the name of serpentine is a hydrated silicate of magnesia, the colour of which—generally some shade of green ranging from a black to a delicate yellow-green—is due to an admixture of the oxides of iron and chromium. Iron is one of the most common of our rock pigments, imparting various shades of black, brown, green, yellow, and red to minerals according to "its degree of oxidation and state of combination." Chromic oxide ($Cr_2 O_3$), which is usually present in serpentine in combination with iron, is a substance used in the arts for the purpose of giving a beautiful green colour to glass, and it forms a valuable pigment in enamel painting. The chromic salts range from green to purple, and a small admixture of chromic oxide increases the variety and richness of the shades of colour, due primarily to the iron.

The rock called serpentine consists, in the main, of the mineral of that name; but much of its beauty depends on the presence of veins of steatite, calcite, magnesite, chrysolite, and other sub-

stances, the deep red veins being due to the ferric, or red, oxide of iron. Indeed, it is to the winding, wriggling, and serpent-like course of these veins, and to their common occurrence, that the rock is indebted for its name.

Many of the specimens of serpentine we examined at the Lizard, especially some of those seen in the Flag Staff quarry, were also remarkable for the abundance of the shining crystals of bronzite they contain. Picotite is another endogenous mineral which is rather plentiful at Lankidden.

The mineral serpentine is not an original component of the rocks in which it is found, but is a secondary product due to aqueous processes which it is the object of this paper to explain. The rocks from which serpentine has been mainly derived are called peridotites because they are all characterized by the predominance of the mineral peridote, which, in England, is more commonly called olivine with reference to its olive-green colour.

Peridotites belong to the ultra-basic class of igneous rocks, and the principal varieties detailed in Teall's 'British Petrography' * are as follows:—

Dunite,	composed	of	olivine and chromite or picotite.
Saxonite	,,	,,	olivine and enstatite.
Lherzolite	,,	,,	olivine, enstatite, and augite.
Picrite	,,	,,	olivine and augite.
Hornblende picrite	,,	,,	olivine and hornblende.†

It is interesting to note, in passing, that some meteorites exhibit a marked affinity with peridotites, containing, like the latter, olivine and rhombic and monoclinic pyroxene. Peridotites and stony meteorites also occasionally contain some basic felspar. This correspondence between igneous rocks that have welled up to the surface of the globe from unknown depths below us, and stony matter that has reached the earth's surface from space, a fact to which my attention was, some years ago, directed by Prof. Judd in his lectures at the School of Mines, is as interesting as it is suggestive.

In a previous paragraph I gave a list of the leading varieties of peridotites which, as I said before, have one characteristic in common, namely, that they consist, for the major part, of olivine;

* p. 103.
† Teall's 'British Petrography,' pp. 97-99.

but you must not suppose that these rocks are commonly met with in a fresh and unaltered condition at the surface of the earth. Olivine is a most unstable mineral that readily absorbs water and passes into serpentine, and consequently olivine rocks that have long been exposed to the inroads of aqueous agents are peculiarly liable to serpentinous alteration.

It is not necessary, I am sure, to point out to you how readily the rain that falls so abundantly at the earth's surface finds its way into strata buried far beneath our feet. The Members of the Association are, as I know, much given to exploring mines, and on these occasions they generally bring back with them lively impressions of the all-pervadingness of water; but, notwithstanding these experiences, all of us do not, perhaps, sufficiently realize how readily water penetrates and permeates the substance of the hardest minerals. It is easy to understand how meteoric water finds its way below the surface through fissures, faults, joints, and cracks, and the well-known existence of deep-seated springs and underground currents, and the success that has in so many places attended deep borings for artesian wells have familiarized most minds with the fact that certain strata, such as chalk and sand, are perfectly porous; but probably it is only the petrologist who is in the habit of studying under the microscope thin slices of such dense and compact rocks as basalt who has sufficiently realized that water not only can, but actually does find its way into the heart of the hardest minerals.

In connection with this important and interesting branch of our inquiry it is necessary to allude briefly to an abstruse and difficult subject.

The elasticity of a gas is explained by what is called the kinetic theory, and several distinguished physicists now extend the application of this theory to solid bodies, and tell us that substances, which to the eye appear to be inert, are made up of moving particles, and that heat, light, and electricity are forms of motion.

According to this theory solid substances are supposed to be made up of atoms and molecules oscillating or vibrating within the limits of certain fixed bounds, but so extremely small that the human eye is unable to detect their motion.

In the case of the molecules of which solid bodies are composed, and in the case of the heavenly bodies, the units are prevented from ranging beyond their proper limits by their mutual attraction,

or, in other words, by the force of gravity. But, according to Boscovitch,* if we desire to account for the properties of matter we must take another element into consideration, and that is the force of repulsion. According to his theory, at an infinitely small distance between the particles of matter there is infinite repulsion. This repulsion decreases in force as the distance between them increases until zero is passed, when attraction, according to the Newtonian law, sets in.

This theory helps us to comprehend why solid bodies, when heated to the requisite intensity, pass first into a liquid condition, then into the gaseous state, and finally become dissociated. The greater the intensity of heat the greater the force of repulsion, and the further the point at which the force of attraction sets in is pushed into the distance.

It may, perhaps, enable us to grasp the idea that the force of repulsion may exist between the particles of matter when brought close together, or when heated, if we reflect on the fact that heat and electricity are so far related to each other that one can be converted into the other, and that two bodies positively, or both negatively electrified, repel each other.

This notion of repulsion is not altogether new. Sir Humphrey Davy, before any of us were born, defined heat as "a peculiar motion, probably a vibration of the corpuscles of bodies tending to separate them," and he called heat a "*repulsive* motion."†

These theories of the ultimate constitution of matter are not only interesting in themselves, but they have a special significance for us, and a direct bearing on the subject of our inquiry to-night. If we desire to understand how it is that water gains access to the heart of the hardest minerals and rocks, and how the interesting chemical and mineralogical changes involved in the conversion of a peridotite into serpentine are brought about, we must dismiss from our minds the notion that the molecules, of which minerals and rocks are composed, are tightly compacted together like the cells of a honeycomb without interspaces between them.

Whether we accept the kinetic theory of matter or not it seems incumbent on us, as petrologists, to believe in the existence of molecular interspaces. This belief, for instance, lies at the root of

* 'Nature,' Oct. 3rd, 1889, p. 545. See also Sir W. Thomson's opening address, Section A, 'Report Brit. Assoc.,' 1884.

† Sir William Thomson's address, *loc. cit.*

the undulatory theory of light, without which we should be utterly stranded in our attempts to explain the optical properties of minerals.

It is necessary to remember the fact of these interspaces when we consider the question of the alteration of minerals by aqueous agency. This alteration does not always begin at the outside of a mineral, and every microscopic petrologist will be familiar with cases in which it has been set up at the heart, and in the internal tissues—so to speak—of a mineral, and when the channels through which chemical constituents have been abstracted, or have been introduced, are too small to be revealed by the microscope. But it must also be borne in mind that besides these invisible pores, rocks abound in cracks and cavities through which the access of water is very much facilitated.

In a paper on the Mineralogy of Scotland, by Prof. Heddle, read before the Royal Society of Edinburgh, the author gives the results of some experiments on the capacity of certain granites and greenstones to absorb water. The granites absorbed from ·139 to ·282 per cent. in twenty-four hours; whilst one of the greenstones, a specimen from Ratho, absorbed during the same period as much as 1·52 per cent. of water.* These experiments were conducted at the ordinary pressure and temperature.

I have myself found, in India, when taking the specific gravities of igneous rocks that some apparently compact specimens were so full of internal pores that streams of minute bubbles would flow from them for so long after they were plunged into water that it became hopeless to correctly ascertain their specific gravity in the ordinary way.

In the human body we know that the blood is carried by the arteries to the small capillaries and distributed through the tissues of the body. Something of the same economy is seen in the mineral world. Fissures, joints, faults, and cracks carry meteoric water down to beds far below the surface and distribute it, often under considerable pressure, among the fine cracks, and capillary pores, that exist in the hardest and most compact rocks.† And although the pressure under which water is put in circulation through the capillary pores depends on the "head" (·43lbs. per

* 'Transactions R. S. Edin.,' Vol xxviii, p. 539.

† See Note on Capillary Flow. Appendix.

square inch per foot in height when there is an unbroken head),* nevertheless, the freedom with which this water flows through the capillaries, if what I have said about the kinetic theory of matter be true, must be sensibly increased by heat. All our text-books contain references to the experiments of Poiseulle, who showed that capillary flow was increased by heat; water at 45° Centigrade flowing three times faster than water at zero Centigrade.

In the case of minerals, we have seen that heat, which is a mode of motion, signifies an increase in the force of repulsion that keeps apart the atoms and molecules of which these minerals are composed. Supposing, therefore, that the pressure under which water was being injected into the pores of a mineral remained constant, heat would facilitate its capillary flow through those pores by reducing the resistance to the passage of the water between the molecules of which the mineral is built up.

I think I have dwelt at sufficient length on the mode in which water finds its way into the heart of minerals and rocks, and it is time to turn to the consideration of what happens when the water arrives there.

The capacity of water to hold carbon-dioxide, and oxygen, in solution is very great. Water at 60° F. is capable of taking up slightly more than its own volume of carbon-dioxide; and meteoric water contains two cubic inches of oxygen, and one cubic inch of carbon-dioxide, per gallon. As rainwater passes downwards into the earth the percentage of oxygen is reduced and that of carbon-dioxide increased. The decay of vegetable matter, and the chemical reactions connected therewith, lead to the consumption of oxygen and the evolution of carbon-dioxide. Professor Heddle, in a paper read before the Royal Society of Edinburgh,† explained, with reference to the above fact, how water acting on the ferrous oxide in minerals might remove it as carbonate when the process went on at some depth below the surface, but convert it into ferric oxide when the reaction took place nearer the surface. The percentage of carbon-dioxide in meteoric water being only half as high as that of oxygen, whilst the whole of the carbon-dioxide was engaged in other reactions, the oxygen might be employed in peroxidizing the iron. Once converted into ferric oxide the iron

* In this paper, I need hardly say, I am considering the condition of strata comparatively near the surface, and not that of deeply buried rocks. In the case of the latter, plutonic heat would presumably obliterate all fissures and cracks.

† *Loc. cit.*, Vol. xxviii, p. 540.

would not be removed by carbonated water, as carbon-dioxide does not combine with ferric oxide.

This process is of especial interest to us as the ferric oxide of iron is so prominent a feature in, and adds so much to the beauty of serpentine rocks.

Prof. Heddle only alludes to the formation of ferric oxide by the action of meteoric water charged with oxygen; but the deposit of magnetite, so frequently seen in serpentine, and in the cracks of olivine, constituting what is known as the *maschen structur*, must evidently be referred to the same cause. The iron present in peridotites in the form of ferrous oxide (Fe O) passes into magnetic oxide (Fe_3 O_4) and into ferric oxide (Fe_2 O_3) by the gradual addition of oxygen. That is to say:—

6 atoms of iron plus 6 atoms of oxygen constitute ferrous oxide
6 „ „ 8 „ „ „ magnetic oxide
6 „ „ 9 „ „ „ ferric oxide.

The microscopic petrologist meets almost every day with cases in which crystals of magnetite are surrounded with red stains of ferric oxide due to the oxidation of the former by aqueous agencies.

The deeper meteoric water sinks in the earth, the more highly, as before stated, it is charged with carbon dioxide, and the more potent an engine of chemical change it becomes. That carbonated water is capable of decomposing the silicate of magnesia and of removing that base in the form of carbonate was proved, experimentally, by Profs. W. E. and R. E. Rogers,* who showed that digestion in carbonated water for a few minutes partially decomposed and dissolved such minerals as hornblende, actinolite, hypersthene, olivine, epidote, and felspar, when in a state of fine powder, and that simple water acted on most of them. And I may state that I obtained enough magnesia to give distinct evidence of its presence on a qualitative analysis by the digestion of powdered olivine in distilled water for three days and nights, during which time it was raised to near the boiling point for 8½ hours, and finally boiled for ten minutes.

Carbonic acid combines readily with ferrous oxide, or, as it used to be called, the protoxide of iron, forming ferrous carbonate, a salt soluble in an excess of carbonic acid. The iron present in olivine is in the form of protosilicate, and as this is decomposed by carbonated water, there is no difficulty in understanding the

* 'American Journal of Science,' 1848, p. 401. See also Bischoff's 'Chemical Geology,' Vol. i, pp. 2, 58.

process by which iron is removed from olivine by the percolation of water through the pores of the mineral. The common occurrence of carbonate of iron in the waters of springs sufficiently attests the frequency with which this reaction takes place in nature.

After the above remarks on the action of carbonated water on the silicates of magnesia and iron, little further explanation will be required to enable us to comprehend the mode in which olivine is, under the influence of aqueous agencies, converted into serpentine by the substitution of water for iron and magnesia.

The formulæ of olivine and serpentine are as follows :—

Olivine (Mg Fe) O_2, SiO_2, or, as frequently written nowadays	$(Mg\ Fe)_2\ Si\ O_4$
Serpentine (Mg Fe) O_3, $2SiO_2 + 2H_2O$, or, as frequently written	$H_4\ (Mg\ Fe)_3\ Si_2\ O_9$
Two molecules of olivine expressed in the terms of the second formula would be written as follows, viz.:	$(Mg\ Fe)_4\ Si_2\ O_8$
If from this one molecule of ferro-magnesian oxide is removed	$(Mg\ Fe)_1\ O_1$
we have	$(Mg\ Fe)_3\ Si_2\ O_7$
And if two molecules of water, viz.: 2 (H_2 O) are added	$H_4\ O_2$
we get	$H_4\ (Mg\ Fe)_3\ Si_2\ O_9$

the formula for serpentine.

As the above change appears to involve an increase of volume, I think it probable that the passage of carbonated water through olivine results in the removal of some of the ferro-magnesian-silicate (without conversion into serpentine) in the form of soluble silica and carbonates.

I have already stated that the principal component of the peridotites is olivine; but, inasmuch as they also contain rhombic and monoclinic pyroxene, and some contain hornblende, it seems desirable to consider briefly the processes by which these minerals are converted into serpentine.

As it would make this paper insufferably long were I to deal with each species separately, I shall content myself with taking enstatite and malacolite as types of the rhombic and monoclinic pyroxenes, and tremolite as the type of the amphiboles. The

formulæ for these minerals given in Dr. Hatch's Petrological Tables are as follows:—

Enstatite (Mg Fe) Si O_3.

Malacolite Ca (Mg Fe) Si_2 O_6 (Al_2 O_3).

Tremolite Ca Mg_3 Si_4 O_{12}.

According to the above, malacolite contains some aluminium-oxide as an essential ingredient; and inasmuch as carbonic acid does not combine with aluminium-oxide, carbonated water is incapable of removing this substance. Hence, as pointed out by Professor Heddle, in the paper already referred to, "a serpentine formed by the alteration of an aluminous mineral must be a more or less aluminous serpentine."

The theoretical formula for serpentine given in the preceding pages does not contain alumina; but all the actual analyses of British serpentines, given by Teall at p. 124 of his 'British Petrology,' contain aluminium-oxide, and out of the 78 actual analyses given by J. D. Dana, in his 'System of Mineralogy,' no less than 39 contain this base. In two instances it amounts to over 5 per cent. of the whole.

As regards the iron in enstatite and malacolite, the processes by which this is removed as carbonate, or deposited as magnetic or ferric oxide, have already been explained.

That silicate of lime is decomposed by carbonated water at the ordinary temperature has been shown by Professors W. B. and R. E. Rogers, and Bischoff; and as the carbonate of lime, which is formed by this reaction, is taken up by water holding carbonic acid in solution, the removal of the lime from the malacolite and tremolite will be readily understood. On the other hand, as pure water does not, at the ordinary temperature, hold calcium-carbonate in solution, the lime, after its extraction from the above minerals, would, in the event of the carbon-dioxide in the water being used up in the course of further chemical reactions, be thrown down in the form of carbonate. Hence calcite veins sometimes occur in serpentine.

The removal of the lime might also be effected in another and more indirect way. Carbonated water readily decomposes the alkaline silicates, and the alkaline carbonates, so formed, react powerfully on the silicate of lime, forming calcium carbonate.

I come now to the last points to be considered, namely, the mode in which the proportion of magnesia and silica in

enstatite, malacolite, and tremolite are equalized so as to form serpentine. The composition of the above minerals given in E. S. Dana's Text Book is as follows:—

	Si	Mg	Ca	H_2O		
Enstatite*	60·40	40	—	—	=	100
Malacolite*	55·6	18·5	25·9	—	=	100
Tremolite	57·70	28·85	13·35	—	=	100
Serpentine	43·48	43·48	—	13·04	=	100

I do not think the equalization of the silica and magnesia can be caused solely by the abstraction of silica; for if we regard the case of malacolite, it is evident that if 25·9 per cent. of lime and 37·1 per cent. of silica were removed, and only 13·04 per cent. of water added, the operation would result in considerable loss of bulk. It seems more probable, therefore, that the equalization is produced partly by the removal of silica and partly by the addition of magnesia.

The silicate of magnesia, we have already seen, is decomposed by carbonated water. It is also decomposed by carbonate of lime, a large amount of which must be manufactured in the conversion of malacolite and tremolite into serpentine. Silica set free by the chemical reaction of acids is commonly in a form that is soluble in water, hence in chemical analyses the solutions obtained are evaporated to dryness in order to convert the silica into the insoluble state. This being so, we shall have no difficulty in accounting for the removal of silica by carbonated water.

As for the addition of magnesia, we have already seen that the major part of peridotites consists of olivine, and that olivine in the process of its conversion into serpentine parts with some of its magnesia. It seems probable, then, that the surplus magnesia, supplied by the olivine, replaces lime in malacolite and tremolite, and the result is the levelling up of the magnesia in these minerals to the proportion required for serpentine.

Bischoff, in his 'Chemical Geology,' says "bicarbonate of magnesia and silicate of lime form bicarbonate of lime and silicate of magnesia. It will subsequently be shown that magnesia frequently replaces lime. It appears in the highest degree probable that this replacement takes place in the above

* The *theoretical* formulæ on which the proportions here given are based do not quite agree with the theoretical formulæ given *ante*. In the one iron and alumina are treated as essential, and in the other as occasional and non-essential constituents.

manner, for bicarbonate of magnesia is frequently present in water, and such water, filtering through rocks containing silicate of lime, will naturally cause this change."*

The conversion of the rhombic and monoclinic pyroxenes and amphiboles into serpentine is evidently a more difficult, or at any rate a slower, process than the change of olivine into serpentine. Olivine is one of the first minerals in a peridotite to undergo serpentinous changes; enstatite follows next, whilst monoclinic pyroxene yields with less facility. One often sees thin slices of rocks in which nearly the whole of the olivine has been converted into serpentine, but in which the alteration of enstatite and augite into this mineral has only begun.

Of the conversion of hornblende into serpentine I have seen few examples; but regarding the reality of the alteration of olivine, and rhombic and monoclinic pyroxene into serpentine by aqueous agencies, no microscopic petrologist can have a doubt. I have in my own collection numerous examples of this process in every stage. Two very beautiful specimens of lavas from the Puy de Dôme, Auvergne, collected by me, are especially instructive. The olivine crystals in them are as big as peas; they are very fresh, but the commencement of alteration may be distinctly seen by the formation of hair-like threads of serpentine running through them. A glance at the actual specimens is sufficient to show that these are not cracks filled with serpentine imported from outside. Had this been the case, the threads of serpentine would have been bounded by the walls of the cracks, and there would have been sharp lines of demarcation between them and the olivine. In these specimens, however, as shown in the wood-cut (Fig. 1), the veins have serrated edges the sharp teeth of which cut into the olivine at a high angle to the direction of the supposed cracks. The passage of the carbonated water in the direction of the veins may have been facilitated by fine cracks, but the operations of the corroding liquid were not confined to these

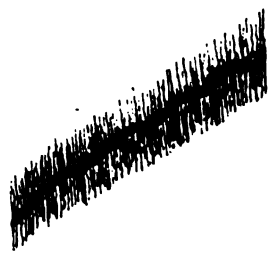


FIG. 1.—Vein of serpentine in olivine crystal, from Puy de Dôme lava, as seen under the microscope.

* *Loc. cit.*, Vol. i, p 13.

cracks, for it is clear that this liquid had begun to eat its way into the pores of the olivine on both sides of the veins in fine parallel lines, which doubtless represent lines of weakness due to the special molecular structure of the olivine.

The Puy de Dôme, it must be remembered, is a volcano of such recent age that it has suffered little from erosion, and has never been buried under strata of later date; and as an essential part of the process by which olivine is converted into serpentine is the absorption of water and the removal of magnesia in solution, it requires no further argument to show that the agent which set up the serpentinous alteration of the olivine in the Puy de Dôme lava must have been meteoric water.

APPENDIX.

Note on Capillary Flow.

Having heard the opinion expressed that the pressure of superposed strata would stop or retard the capillary flow of water through porous rocks, I consulted a professional engineer on the subject. He replied as follows:—

"The weight of strata cannot influence the flow of water through it in the least degree. Pores, fissures, and cavities hold water simply as pipes or vessels, and follow the same hydrostatic or hydraulic laws, and pressure is due to the head of water alone.

"For instance, take the case of the Severn Tunnel, which is buried in the ground some 190 feet maximum from the surface; the strata being porous and fissured, and holding water almost to the top. Water weighs ·43 lbs. per square inch per foot in height, and this multiplied by 190 gives about 80 lbs. per square inch pressure. Pressure-gauges were put up all along the tunnel, and the actual pressure registered was everywhere equal to the calculated pressure wholly uninfluenced by the weight of the strata."

Since the above was written the following tables, which refer to a part of the tunnel where the depth from the surface was less than the part referred to in the foregoing extract, have been furnished me by a gentleman under whose directions the experiments were watched. The procedure followed was as follows:—The surrounding country was pumped dry during the construction of the tunnel. When the pumping ceased the strata

gradually refilled with water. The third and sixth columns show the actual height of water in feet as the water rose gradually to its normal height, and the second and fifth columns show the actual pressure registered at the gauge. The results of those experiments showed that there was an unbroken head of water from the bottom of the tunnel to the surface of the country.

Severn Tunnel.

Table showing rate at which pressure rose in the strata.

Date.	Pressure in lbs. per sq. inch.	Head of Water in feet.	Date.	Pressure in lbs. per sq. inch.	Head of water in feet.
1885.			1885.		
Aug. 11 ...	Nil.	Nil.	Sept. 8 ...	46¾	107
„ 12 ...	9	21	„ 9 ...	47	108
„ 13 ...	12	28	„ 13 ...	47¼	109
„ 14 ...	17	39	„ 14 ...	47½	109
„ 15 ...	18¾	43	„ 15 ...	47¾	110
„ 16 ...	21	48	„ 17 ...	48	110
„ 17 ...	22½	52	„ 18 ...	48¼	111
„ 18 ...	25	58	„ 20 ...	48¾	112
„ 19 ..	27	62	„ 22 ...	49	113
„ 20 ...	29¼	67	„ 25 ...	49¼	113
„ 21 ...	32½	75	Oct. 1 ...	49½	114
„ 22 ...	34¾	80	„ 4 ...	49¾	114
„ 23 ...	36½	84	„ 7 ...	50	115
„ 24 ...	37½	86	„ 10 ...	50¾	117
„ 25 ...	38¾	89	„ 11 ...	51	117
„ 26 ...	39¾	91	„ 15 ...	52¼	121
„ 28 ...	40	92	„ 17 ...	53	122
„ 29 ...	41½	95	„ 24 ...	53½	123
„ 30 ...	42½	98	„ 27 ...	54	124
„ 31 ...	43	99	„ 31 ...	54½	125
Sept. 1 ...	43½	100	Nov. 4 ...	55	127
„ 2 ...	43¾	101	„ 7 ...	55½	128
„ 3 ...	44½	102	„ 9 ...	56	129
„ 4 ..	45¼	104	Dec. 3 ...	57	131
„ 5 ..	45½	105	„ 7 ...	57¼	132
„ 6 ...	45¾	105	„ 20 ...	57¼	132
„ 7 ...	46¼	106			

On the Occurrence of Amberite in Coal, at Kawa Kawa Colliery, Bay of Islands, New Zealand.

By T. Pearson Moody, M.E.

(Read 2nd May, 1890.)

Amberite, ambrite, or retinite is a fossil gum or resin; and, like most bitumens, it contains upwards of ten per cent. of oxygen, and also nearly the same proportion of hydrogen. It resembles "Kauri Gum" very closely, and similar ornaments are made of it. They are, however, generally more brittle than the genuine article.

This peculiar substance imbedded in a coal-seam I have never seen anywhere but at the Bay of Islands, at Waikato, and at a place called Whangarei, situated 40 miles south of Kawa Kawa.

In association, and intermixed with our coals, very considerable quantities are obtained. It frequently occurs in larger masses, but generally is found in layers of very limited extent, and in "nodules" extensively disseminated over the faces of the coal.

Its hardness may be represented by 2; specific gravity, say, 1·034; lustre resinous; colour yellowish-grey, sometimes light and dark green; occasionally encrusted with films of carbonate of lime and spar; sub-transparent; strongly electric on friction, and possessing a conchoidal fracture.

Its chemical composition is as follows:—

Carbon	... 76·88
Hydrogen	... 10·54
Oxygen	... 12·76

It appears to be wholly insoluble in alcohol, ether, oil of turpentine, benzole, chloroform, and dilute acid, and burns with a yellowish smoky flame. The ash contains iron, lime, and soda.

In close proximity to the amberite, I have frequently met with specimens of calcite and pyrites. These probably are due to the infiltration of water from the sub-crystalline limestone and the decomposition of the sulphur in the sandstones, which form the roof of our coal-seam. The geological age of these is Cretaceo-tertiary, and they repose on the diorite slate. The green sandstone which forms the roof of our seam of coal, and slabs of which may be seen at the British Museum, contains most magnificent specimens of Lamellibranchiata and Gastropoda.

I am inclined to the opinion that this fossil gum is an exudation

from the Kauri Pine (*Dammara australis*) changed by chemical action of some kind, the main difference between it and Kauri gum being colour. Amberite is, I am informed, met with in the coal in the southern portions of New Zealand.

The amber of the Baltic coast, as is well known, occurs in irregular masses without cleavage. Its hardness is 2·25; specific gravity 1·065 to 1·081; lustre resinous; colour yellow, but sometimes reddish, brownish, or whitish, and often clouded. Its streak is white, and it is transparent, tasteless, and electric on friction.

Its composition is:—

Carbon	78·824
Hydrogen	10·228
Oxygen...	10·900

Geomyricite, again, is wax-like and white in colour; melts at 80° to 90° Fah.; is easily soluble in hot alcohol and ether, though but slightly in 80 per cent. alcohol. This is thought to be the resin exuded from some palm.

Its composition is:—

Carbon	80·59
Hydrogen	13·42
Oxygen	5·99

This substance is, I think, almost identical with Chinese wax. It is only reasonable to suppose that these fossil gums, or resins, are the exudations of trees that flourished at the time the deposits in which they are found were forming. The strata from the surface to the coal, where the amberite is found, are exhibited by the following section:—

	Ft.	In.
Soft clay mixed with gravel and boulder sandstone ...	81	0
Marley Greensands.		
Hard calcareous bluish sandstone with shells	97	10
Coal Formation.		
	Ft.	In.
Hard bluish sandstone	7	10
Hard coal	4	8
Hard brown fire-clay	7	0
Hard coal...	5	9
Soft brown fire-clay	0	4
Hard coal...	2	9
Hard dark sandstone	3	0—30 11
Underneath—*Dioritic Slate.*		

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Coal Formation.		
Hard bluish sandstone	7	10
Hard coal	4	8
Hard brown fire-clay	7	0
Hard coal...	5	9
Soft brown fire-clay	0	4
Hard coal...	2	9
Hard dark sandstone	3	0—30 11
Underneath—*Dioritic Slate.*		

At a point a quarter of a mile distant from the foregoing section I proved, by diamond boring, a bed of sub-crystalline limestone (almost a marble) 248 feet thick, reposing upon the bed of green sandstone.

Above this limestone is a bed of argillaceous (hydraulic) limestone 220 feet thick. I merely mention this to show that it is probably from these upper beds that the calcite and pyrites have their origin. I would mention that the Kawa Kawa coal area is a very broken one, being much affected by faults.

An examination of the coal-seam shows it to be of terrestrial origin. In the less pure portions the seam is of a shaky character, and at such places there are indications of its being partly formed of sedge-like plants. In the underclay rootlets are abundant.

There is but a thin bed of underclay between the coal-seam and the Palæozoic rocks on which the coal-beds repose. This bed of clay is not more than one foot thick at the outcrop, but its thickness gradually increases at the dip to seven feet.

The coal undulates in conformity with the surface (which is greatly undulatory in its character), and has a tendency to increased thickness in the hollow between the greater ridges. The Coal-measures dip one in six, *S.* 70° *W.*

Sir James Hector, K.C.M.G., Director of the Geological Survey of New Zealand, says:—

"The coal in the extreme south contains large masses of Amberite, which cannot be distinguished from the best old gum. The strata also contains abundance of Kauri leaves, and Kauri timber is found fossilized in New Zealand as early as the Triassic period."

Mr. James Park, F.G.S., Director of the School of Mines, Thames Goldfields, says:—

"Retinite occurs in Coal-measures all over our Colony. Several species of Kauri lived during the coal period from Southland to Auckland, and I think Retinite is most probably derived from these."

Professor F. G. Hutton, F.G.S., of Canterbury College, Christchurch, N.Z., writes as follows:—

"1.—The fossil resin (Ambrite) from New Zealand is found in many of the coal-fields of Otago and also at Preservation Inlet, but not in Brunnerton or Westport Coal, but plentifully at Reefton and Blackball mine, near Brunnerton. Of course there is no

Kauri there. The name Ambrite was given by Hochstetter to some resin taken to Europe.

"2.—The New Zealand coals are, I believe, formed principally from wood of various trees; some of them may have been species of *Dammara*, but not necessarily so, for resin is found in all the *Coniferæ*.

"The living Kauri is *Dammara australis*.

"Two Tertiary species have been described, *D. Oweni* and *D. uninervis* from Shag Point and Malrera Hills; one Cretaceous species, *D. Mantelli*, from Pathawau, Nelson province, and a piece of wood of Triassic age from Richmond, near Nelson, has been called *D. fossilis*, but it is doubtful and might be *Araucaria*.

"The resin found in coal is generally believed to have come from the *Coniferæ*, because insects have been found in it. There is an old theory of Bischoff's that it might have been produced from wood during its formation into brown coal in brackish water; but nobody thinks so now, and I fancy Bischoff did not really believe it himself. I have seen large lumps of Ambrite in Sandstone at Caversham, near Dunedin. If you burn Ambrite and Kauri gum (resin properly), you will find by the smell that they are different.

"The climate of New Zealand was formerly warmer than at present, and species of *Dammara* may and did live here then; but the true Kauri, *D. australis*, has never been found in the South Island, living or fossil, neither has Kauri gum."

Professor A. P. W. Thomas, M.A., of University College, Auckland, remarks:—

"Hochstetter was of the opinion that the Ambrite was not Kauri gum, basing his opinion on the chemical composition of Kauri gum and Ambrite respectively; but I doubt whether the chemical evidence is sufficient on this point, for changes in composition would take place in the course of time. I think the identification of the Ambrite as coming from any particular tree is impossible until further evidence is collected."

Dr. Ferdinand Von Hochstetter, Professor of Geology and Mineralogy at the Polytechnic Institution of Vienna, who in 1858 accompanied the 'Novara' Expedition to the South Pacific Islands in the capacity of geologist, in his 'New Zealand; its Physical Geography, Geology, and Natural History,' referring to the first coal-field examined in the Hunua district, situate twenty miles south of Auckland, observes —

"A Fossil Resin is very frequently found imbedded in the coal, sometimes in pieces from the size of a fist to that of a man's head, but usually only in smaller groups.

"It is transparent, very brittle, and has a conchoidal, and quite glossy fracture. The colour changes from a bright yellow to a dark brown. It is easily ignited, much more so than Kauri gum. burns with a steady, fast, sooting flame, and develops a bituminous rather than aromatic smell.

"Although originating probably from a coniferous tree related to the Kauri pine, it nevertheless has been erroneously taken for Kauri gum.

"Mr. Richard May found as a mean result of three chemical analyses of this fossil resin :—

Carbon	76·65
Hydrogen	10·38
Oxygen	12·78
Ash	0·19
	100·00

yielding the formula $C_{32}\ H_{26}\ O_4$. It shows great indifference to solvents. By friction it becomes electric. Hardness, 2; specific gravity, 1·034 at 12° R.

"It is sufficiently characterized to deserve a special name; but it comes so near to '*real amber*,' that it deserves the name of 'Ambrite.'"

There is no reason to suppose that the range of the Kauri has originally been other than it is now. Three degrees of longitude, and three degrees of latitude encompass the entire range of this remarkable tree; and even within those narrow limits the Kauri has at all times been by no means a common tree. Extensive districts, moreover, within that range which formerly were covered with Kauri woods are now totally destitute of it, and the extermination of this noble tree progresses from year to year at such a rate that its final extinction is as certain as that of the Maoris.

Note on a New Species of Capulus.

By G. S. Boulger, F.L.S., F.G.S., Professor of Geology, City of London College.

(Read May 2nd, 1890.)

Nearly two years ago my friend Mr. N. F. Robarts, F.G.S., communicated to me three small specimens which he had received from Mr. John O'Callaghan, of Ayr. They were obtained at Muirkirk, on the Garpel, a tributary of the Ayr, in Lower Carboniferous Limestone, associated with abundance of *Productus latissimus*, and below the limestone containing *P. giganteus*, perhaps in what are locally known as the Craigenglen Beds. Of the three fossils one was a fragment of *Productus*, showing the longitudinal ridge and dendritic muscle-impressions. The second is still a puzzle to me, being a straight, or slightly tapering, apparently calcareous, structure, over half an inch long, with finely crenulated articulations at frequent intervals throughout its length. Is it a coralline or a spine?

When I received it, the third specimen was not very promising, only a small portion projecting from the limestone matrix; but, as this portion exhibited well-defined colour-bands, I thought it worth while to have it carefully developed. Guesses previously hazarded as to its being *Terebratula hastata* or a *Euomphalus* were then at once shown to be fallacious, and the spiral shell, which you now see, was uncovered. Even then its generic determination was not devoid of difficulty. Externally it is very like some species of *Nerita*, in which genus radiate colour-bands are not uncommon; but whilst no true nerites are known from Palæozoic rocks, there is no indication in this specimen of the thick shell or thick outer lip of that genus, neither in this specimen is the shell an entirely close spiral. Still more did I feel tempted to refer it to *Natica* or *Naticopsis*, a group well represented in the Carboniferous, and one in which colour-markings are very indestructible, and are frequently preserved in a fossil state. In form, indeed, this specimen, though smaller, strikingly resembles one specimen of *Naticopsis plicistria*, Phillips, in the British Museum (B.M. 97381) from the Carboniferous Limestone of Lancashire. Not only, how-

ever, has *Naticopsis* always a close spiral and a more globularly inflated body-whorl, but apparently a plain, rounded aperture, and simply concentric, and but slightly defined, lines of growth seem also characteristic of the genus.

Such considerations drove me to the *Calyptræidæ*, or Bonnet Limpets, an interesting but difficult group. They adhere to stones, to dead shells, or even to living echinoderms, never apparently quitting the spot on which they first settle, so that the margins and even the whole form of their shells become adapted to the surface on which they are attached. Their colour is often protectively like that of the object to which they adhere.*

Mr. Robert Etheridge, junior, following de Koninck, has pointed out† that the generic name *Capulus* of de Montfort‡ has precedence over *Pilcopsis* of Lamarck (1812), *Platyceras* of Conrad (1840), and *Acroculia* of Phillips (1841), as referring to the great majority of Palæozoic *Calyptræidæ*. Following de Koninck,§ the shell in the genus *Capulus* may be described as in the form of an oblique cone, irregularly recurved behind, with a tapering and very often spiral apex, an aperture oval or rounded, sides more or less plaited and irregular, and the muscular impression horse-shoe shaped, open in front with slightly unequal branches. It is distinguished from *Patella* by its want of symmetry, its much more elongated form, and its inrolled apex; and from *Hipponyx* by the absence of the calcareous base formed in that genus.

Conrad founded his genus *Platyceras* for *Pileopsis tubifer*, *P. vetusta* and *Nerita haliotis* of Sowerby, the shells of which are, he says,‖ "suboval or subglobular, with a small spire, the whorls of which are sometimes free and sometimes contiguous; the aperture is generally campanulate or expanded." Phillips' *Acroculia*¶ was founded upon the same group of forms. Prof. Hall maintained Conrad's genus** on the ground that the

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‡ 'Conchyliologie systématique,' tom. ii, p. 55.

§ *Op. cit.*, p. 168.

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horse-shaped muscular scar, characteristic of *Capulus*, had not been detected in the Palæozoic forms. This has, however, since been found more than once by Messrs. Meek and Worthen,* so that we may assume other species, externally similar, to belong also to *Capulus*, and do not need Conrad's *Platyceras* or Phillips' *Acroculia*.

Referring to their generally fixed position, de Koninck mentions, as do also Messrs. Meek and Worthen, the fact that *Capulus* is often attached to crinoids or cystideans. S. P. Woodward refers† to the occurrence of the living *C. ungaricus* on oysters, and among the recent shells in the British Museum are specimens of *C. crystallina*, Gould, from Mauritius, on a star-fish, and of *C. granulata*, A. Ad., from West Africa, on an echinoid spine.

Mr. F. A. Bather, F.G.S., has kindly referred me to four interesting papers by Mr. Charles R. Keyes on this subject,‡ and has shown me a specimen in the British Museum of the Silurian *C. haliotis* (described by Sowerby as a *Nerita*) attached to the upper surface as a crinoid, so as to feed apparently upon the excrement of the echinoderm.

Capulus, though, as we should expect from its antiquity, world-wide in its distribution, is now quite a small genus, Woodward only mentioning eight species, and these apparently are all of small size, and have plain rounded apertures. In Palæozoic times, however, it was otherwise, the genus being well represented in the Ordovian, and de Koninck describing 36 Carboniferous species alone, some of which are of considerable size. These he divides into three sections: *Pileopsidei* (the *Orthonychia* of Hall in 1843), with free whorls; *Neritoidei*, with contiguous whorls; and *Spinosi* (Conrad's *Platyceras*), with points or spines on the surface.

Having determined its genus it was by no means easy to determine the specific position of this fossil, the difficulty being

* 'Illinois Geol. Report,' 1868, Vol. iii, p. 385.

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the fixing upon any satisfactory specific characters in so variable a group. In several species the spire seems to be far more prominent in some specimens than in others; and attachment may no doubt modify the form of the aperture throughout life. Mr. Keyes apparently thinks that this cause renders external form entirely valueless as a specific character in this group. Nevertheless I think that the number and freedom of the whorls, dorsal keels, longitudinal folds, and regular lines of growth determining the form of the aperture, may together furnish all that we can expect as differentiæ.

The types of Phillips' *Pileopsis neritoides* (*Capulus neritoides*, de Koninck) are two specimens in the Gilbertson collection in the Natural History Museum, whilst in the general collection in that Museum there is another much smaller specimen labelled *Acroculia neritoidea*, Phill., considered, that is, to be the same species. Phillips' type-specimens are two somewhat dissimilar shells, each about the same size as that from Muirkirk. They are massive, have an apex of two contiguous whorls, are flattened on the right side, have a lateral aspect almost circular, a back well rounded but irregularly plaited, and a surface marked throughout with widely sinuous lines of growth and considerable rugosities parallel to them. If these be Capuli, they would belong, in spite of some general resemblance to the Muirkirk form, to de Koninck's section, *Neritoidei*, and not to the *Pileopsidei*. As the figures in the 'Geology of Yorkshire' are all but worthless, I have re-figured this species from the type-specimen (Plate IV., Fig. 6).

The small specimen in the general collection I have also included in the Plate (Fig. 7). I should hesitate to refer it to *C. neritoides*. It is undoubtedly very similar to the Muirkirk form, and may be a young specimen of the same species; but the specimen is little more than a cast, and exhibits, where the shell is preserved, fine radial ribs. *C. neritoides*, var. *Simpsoni*, of Mr. R. Etheridge, junior,* also seems nearly allied; but, unfortunately, the type is in private hands in Scotland, and the figures in the 'Geological Magazine' (reproduced Plate IV., Fig. 9) are not good. The pronouncedly inrolled spire, the fine concentric striæ, with stronger laminæ of growth at intervals, are common to both forms; but I do not understand the

* 'Geol. Mag.,' *loc. cit.*

"feebly sinuated edges" or the tendency of the spire to become horizontally coiled, described by Mr. Etheridge, to be represented in my species.

Still nearer, I consider, are de Koninck's two species, *C. eductus* and *C. angulatus*, both from the "calschiste de Tournai." The first of these (Fig. 5) is, however, distinguished, in my opinion, by having a dorsal keel, thick longitudinal folds, and an irregular aperture; and the latter (Fig. 4) by two dorsal keels and a sub-triangular mouth. I have, therefore, ventured to describe this specimen as a new species in close proximity to these two; and, in accordance with the wish of its discoverer, Mr. O'Callaghan, I have dedicated it to Margaret, daughter of our friend Mr. Robarts. It may be described as follows:—

Capulus margarita, sp. nov. Apex, of one whorl, free from the second, which is at once widely dilated; the spiral apex flat on the right side, which is also flat; the lateral aspect semi-circular; the back well rounded and not keeled or plaited; the surface marked by widely sinuous lines of growth, most defined near the apex, but extending to, and determining the outline of, the aperture, with very slight rugosities parallel to them at intervals. The aperture is semi-elliptical. The shell is light-brown, marked by radiate dark olive-green colour-bands, varying in width, widening towards the aperture, and occupying the greater part of the surface. It measures 23 mm. in length, 14 mm. across the aperture from right to left, and 17 mm. across it from front to back.

Mr. Robarts has kindly offered to defray the expense of a partially coloured plate, drawings for which, including views of some of the nearest allied species, have been most carefully prepared by Mr. Berjeau, F.L.S.

In conclusion, I must acknowledge my great indebtedness to Messrs. R. Etheridge, F.R.S., E. A. Smith, J. W. Gregory, F. A. Bather, B. B. Woodward, and C. D. Sherborn, of the British Museum, for advice and assistance.

EXPLANATION OF PLATE IV.

FIG. 1. *Capulus margarita*, sp. nov., from Muirkirk, Ayrshire. Lateral aspect. Natural size.

„ 2. The same, enlarged 4 times.

„ 3. „ equally enlarged. Dorsal aspect.

„ 4. *C. angulatus* de Koninck, from Tournai. Dorsal aspect. After de Koninck.

FIG. 5. *C. eductus* de Koninck, from Tournai. Dorsal aspect. After de Koninck.

„ 6. *C. neritoides* de Koninck. Lateral aspect. Natural size. From the type-specimen in the Gilbertson Collection, British Museum.

„ 7. *C. neritoides* de Koninck, or young form of *C. margarita*. Lateral aspect. Natural size. From a specimen in the General Collection, British Museum.

„ 8. Sinuous aperture of shell of *C. haliotis*. Lateral aspect. From specimen in the same Collection.

„ 9. *C. neritoides*, var. *Simpsoni*, R. Etheridge, junior. Three aspects. Natural size. After R. Etheridge, junior.

ON AN INSTANCE OF RECENT EROSION NEAR STIRLING.

BY HORACE W. MONCKTON, F.G.S.

(Read June 6th, 1890.)

In 1874 an old overgrown pond was repaired to give a supply of water for some ponds belonging to the Howietown Fishery, near Stirling.

The pond is situated in the course of a small stream, which runs from S.W. to N.E. down a steep valley caved out of basalt. Glaciers have flowed over this valley, and patches of boulder-clay remain here and there, in one of which the pond has been dug out.

When the pond was repaired in 1874 an overflow channel was made, leaving the stream about 80ft. above the pond, curving round its edge at a distance of 20 to 25ft., and re-entering the stream 40ft. below the pond's head.

This overflow channel is usually dry, but when the stream is flooded the whole of the water is turned away from the pond into the channel, thus protecting the pond from overflow and from silting up.

The channel was originally made about 6ft. wide and 2ft. deep, and at the lower end there was a fall of about 4ft., over which the water flowed.

The upper part of the channel retains its original size, but the waterfall at the lower end gradually cut back, until the lower 75ft. formed a slight incline. During the process the channel has been greatly enlarged, and it has now reached a depth of from 6ft. 7in. to 7ft. 8in., and a width of from 12ft. 2in. to 17ft. 6in.



7 9 4



3 1 2



8 6 5

Berjeau & Highley del et lith. West, Newman imp

CAPULUS MARGARITA., *sp. nov., and allied forms.*

The greater part of this enlargement appears to have taken place during the first few years after the making of the channel, and though portions of the side occasionally fall in, the rate of erosion seems to be now very much reduced. The whole of the channel is eroded in boulder-clay, and the bottom is now covered with boulders of all sizes, the clay in which they were embedded having been washed away, and these boulders have probably done much towards protecting the bed of the channel from further erosion, and possibly, too, the clay which forms the sides is becoming hardened by exposure to the air. In any case there can be no doubt that the alteration of the course of the stream in 1874, though it did not increase the water power, gave rise to conditions highly favourable for erosion, and the stream at once proceeded with the work, and carried it on rapidly and effectively. Then conditions became less favourable for erosion, and though the power remains the same, the work done has become less, and, indeed, a condition of comparative repose seems to have ensued.

This and other instances of erosion which I have observed in progress have convinced me that mere lapse of time has very little to do with the progress of denudation—it is a question of favourable or unfavourable conditions. If favourable conditions happen to concur, the work of denudation will be carried out rapidly and effectively; whereas, if the reverse is the case, the same amount of work may take ages to accomplish, though the power may be exactly the same.

For instance, ice-worn surfaces of rock remain for a great length of time showing glacial striæ, for, as Professor Geikie observes, they are peculiarly well able to withstand subaërial agencies of waste ('Trans. Geol. Soc. Glasgow,' iii, 175), or, in other words, the conditions are most unfavourable for denudation. Again, M. Élie de Beaumont mentions districts in Brittany and in Spain where old furrows made by the plough remain protected by turf, though the land has not been cultivated for centuries ('Leçons de Geologie,' 1845, Vol. i, p. 165).

We frequently see estimates of geological time based on calculations of the amount of sediment carried to the sea by rivers, and I think that such calculations are sometimes used very fallaciously. For example, if the Mississippi carries to the sea each year an amount of sediment equal to $\frac{1}{6000}$ of a foot of rock from its drainage-area, then, assuming that conditions

will remain the same in 4,500,000, the whole area will be brought down to the sea-level (Lyell, 'Student's Elements," 1878, p. 93; Croll, 'Climate and Time,' 1875, p. 329).

This calculation is of interest as showing what slow but steady denudation can effect, but that is all, for the result cannot be true practically, since apart from other possible changes of condition, the mere fact of alteration in level by denudation would be a change of condition which would render the calculation untrue.

But beyond this such calculations are of little practical value for two reasons.

1st. If we knew the average annual rate at which the surface of the world has been lowered by denudation, it would be of no real use in the calculation of geological time, for we should be unable to apply it to particular instances unless we knew how far those instances differed from the average.

2nd. The amount of work which a river can do in a given time under given conditions is no guide as to what another river will do or to what the same river will do under other conditions.

To show this, I think I need only mention that whilst the Mississippi removes an amount of sediment equal to one foot of rock off its drainage-area in 6,000 years, the River Po is given as doing the same proportion of work in 729 years (Geikie, 'Trans. Geol. Soc. Glasgow,' Vol. iii, p. 153); or, to take another instance, the amount of sediment carried from the total area (1,200 square miles) of the Muir Glacier, in Alaska, has been calculated to amount to $\frac{1}{3}$ of an inch per annum (Wright, 'Ice Age in North America,' p. 64), or 1 foot in 36 years. The calculations for one river are therefore useless if applied to another river, and the calculations for one area useless if applied to another where the conditions differ; and it is ridiculous to apply calculations made from the Mississippi to rivers in England, as I have seen done.

But calculations founded on work done by the Mississippi now are but a poor guide to what it did in former times, for conditions have greatly altered. The amount of work done by a river, for instance, in carrying sediment to the sea is increased by the presence of man. Agriculture, mining, with its spoil-banks, brick-making, quarrying, railway- and road-construction, and steamboats, which stir up and pass on sediment,

are concurrent conditions very favourable to denudation which have only been introduced in recent times. Again, denudation is much affected by elevation or depression of the land, and we have good evidence of considerable alterations in the basin of the Mississippi, even so lately as 1811-12 (Lyell, 'Principles,' 11th ed., 1872, Vol. i, p. 452, Vol. ii, p. 106). It is, in the case of the Mississippi, as in that of all rivers, a question, not of time, but of conditions under which the river worked, and conditions are ever varying. In all cases too conditions favourable and unfavourable to denudation co-exist, and, to a greater or less extent, neutralize one another, so that the real question is what was the result of the balance of concurrent conditions at any particular time.

In some places, and at some times, the progress of denudation is, and has been, greatly in excess of the average, and *vice versâ*. For instance, the progress of denudation in the south and south-east of England must have been very great during and at the close of the Glacial Period, for —

1st. It is admitted that vegetation goes far to check denudation, and at that time much of the surface would probably be denuded of vegetation.

2nd. Much of the surface would be ploughed up by land-ice or covered with boulder-clay, and upon the retreat of the ice left in a state very suitable for denudation by rain, streams, and rivers.

3rd. The retreat and melting of the ice would be accompanied by floods and an increase in the water in rivers.

4th. The destructive power of rivers would be increased by floating ice, which would (*a*) wear away the beds of the rivers; (*b*) cause further floods by temporarily blocking up their channels.

This period of concurrent favourable conditions would continue for some time after this final retreat of the ice, but gradually, as under the influence of a temperate climate the surface became covered with vegetation, the excess of denudation would cease, and a state of comparative repose would ensue. It is, therefore, almost as ridiculous to calculate time on the assumption that the rate of denudation in this area has been uniform in the past as to apply calculations based on the Mississippi to the rate of denudation of the Muir Glacier of Alaska.

The following note, supplied to me by Mr. R. S. Herries, is so much in point that I append it to my paper:—

"The following account of an example of rapid denudation was furnished to me by my brother, Mr. W. Herries. It is written from a settlement in the valley of the Thames, in the North Island of New Zealand, and is dated February, 1883. 'Our next neighbour, Mr. R—, has a splendid example of denudation on his land. Last year he cut an outfall drain from his swamp to the river, about a quarter of a mile long or rather less, 10ft. deep, and about 8ft. wide at top. This has gradually cut away till it is now a big gully about 10 chains broad and 50ft. or more deep, with a magnificent waterfall at the swamp where the drains come in. It is still cutting back, and I hear to-day that he has been obliged to shift his bridge again. Its soil is a light sand, something like the Bagshot. The swamp, however, is clay, so I should think it would not cut away so much there when it gets into it.'"

The increase by denudation in less than a year of the width of a drain from 8ft. to 220yds., and of the depth from 10ft. to 50ft., seems an excellent illustration of a force, tremendous indeed when in operation, but quite passive till called into action by the hand of man.

The Auriferous Series of Nova Scotia.*

By Geoffrey F. Monckton.

(*Read 6th June, 1890.*)

Although Nova Scotia is, with the exception of Newfoundland, the nearest of the large British colonies to England, it is probably the one least known to Englishmen. Until the completion of the Intercolonial Railway connected Halifax with the Canadian Provinces and made that city the winter port of the Dominion, the stream of traffic for the most populous part of the country flowed entirely through the United States in

* During the last century the mines of Nova Scotia appear to have been neglected. On the 13th October, 1757, Lieutenant-Governor the Hon. Robert Monckton wrote to the Lords of Trade:—"I have no doubt but that there may be found great quantities of iron ore in the colony, but there has not hitherto been any attempts to make iron here, nor have we at present any prospect of such a manufacture being undertaken." And on May 22nd, 1758, Governor Lawrence wrote that it was not practicable to open a colliery for want of troops to protect the workmen.—H. W. Monckton.

winter, passing in summer, as it does now, along the St. Lawrence. Nova Scotia, therefore, lay between two ocean highways, neither of which benefited her in the least. For two reasons her mineral wealth has been neglected. The country was thickly covered with forests, which could be turned into cash at a small cost and without any great risk, and her rich fisheries afforded an easy living for her sons, both of which industries were materially assisted by her wonderful series of deep harbours, a valuable legacy from the Glacial Period. The result of this is that at the present day she owns more shipping in proportion to population than any other country, and while her sons are found sailing on every sea, there is always a want of men at home.

I do not propose to deal at length with any of her mineral resources except gold, but it may not be amiss to recapitulate some. The coalfield of Cape Breton extends over 190 square miles, and the measures dip under the sea, whither they will doubtless be followed for some distance. There are not less than eleven seams of coal here, aggregating fifty-one feet which are workable. The Pictou coalfield is only twenty square miles in extent, but the thickness of coal is in five seams about fifty-six feet, one seam being twenty-five and one fourteen feet. The Cumberland coalfield has not been much worked, as the want of facilities for shipping has retarded its development till of late years. It covers a considerable area, and the best section of it, that along the Joggins shore, where in a distance of ten miles 14,000 feet are exposed, has been the subject of many scientific papers. At Springhill Colliery up to the present time seven workable seams, containing forty-nine feet of coal, have been found. Two of these are eleven feet each. Besides these there are the coalfields of Port Hood and Antegonish (probably one) and Little River in the south of Cape Breton. It is also the opinion of Sir J. Dawson that the coal-seams of Pictou will be found by boring to extend over a larger area. Beds of ironstone are plentiful in the Coal-Measures. The Londonderry Iron Company have worked for some years an important vein of iron ore of Upper Silurian age. It consists chiefly of limonite with small quantities of spathic ore and ankerite, and contains about 55 per cent. of metallic iron, varying in width from eight feet to twenty feet. Other deposits of the same kind are known, as at Brookfield,

twenty-five feet wide, and on the East River of Pictou. The last is within a few miles of the Pictou coalfield, and one of the lodes is forty feet thick. No mining operations have been carried on till lately on it, but it is now about to be opened on a large scale. The Devonian rocks of the Annapolis Valley contain some very rich beds of hæmatite. The production of iron ore last year was only 42,000 tons, and of coal 1,774,000, but as furnaces are now being erected at New Glasgow, which will require 160,000 tons of ore annually, and preparations are being made for the export of the Annapolis ore to the United States, a few more years will probably see a very large increase in the output of both minerals.

The numerous veins and beds of copper have never had a fair trial, although the little prospecting done has shown several promising lodes. Extensive workings are now to be prosecuted on the lode in the Laurentian strata of Cape Breton. Lodes carrying galena are very common in the Auriferous Series, but appear to be of no value. In the Carboniferous Limestone large quantities occur, but are rarely concentrated enough to work. At Gays River it may be found anywhere in the limestone, but only in the proportion of 2 per cent. One of the most widespread minerals is sulphate of lime, the export of which for 1889 amounted to 125,800 tons. This occurs in the Lower Carboniferous. There are cliffs of it along the St. Croix River 120 feet high, and at Plaister Cove and St. George 150 and 200 feet high. Manganese, iron, ochre, barytes, antimony, and other minerals also occur, and are worked on a small scale.

The *Auriferous Series* are at present referred to the Cambrian, and supposed to correspond to the Longmynd group. They extend over an area of between 6,000 and 7,000 square miles, of which about fifty are taken up as claims for mining purposes. They occupy nearly the whole Atlantic coast and the north of Cape Breton.

Sir C. Lyell first called attention to the probability of the occurrence of gold in Nova Scotia. By some, the credit of the first actual discovery has been given to the late Rev. Dr. Honeyman, who was an Honorary Member of the Geologists' Association. Indications were found by Mr. J. Campbell in 1859, but it does not seem that he actually found gold. The official report states that a man, stooping to drink at a brook in

Tangier, in 1860, found a nugget among the pebbles, which led to the discovery of the Tangier district, where works are still carried on. In 1860 and 1861, 6,000 ounces were produced. Wine Harbour, Goldenville, and Waverley were all found that year.

This series consists of beds of very hard blue and grey felsitic quartzite, weathering white on long exposure, when it may be easily mistaken for sandstone, and beds of dark clay-slate. Granite occurs in several places. The lodes are as a rule interlaminated with the slate beds, which they sometimes cross, but do not cut the quartzite beds (Fig. 1). Cross lodes occur faulting them, which do not contain gold, but sometimes small productive veins known as "anglers" cross the intervening quartzites, and have the reputation of making or robbing the lodes they strike. The beds are thrown into a series of sharp anticlinals, the axes of which run W.S.W. and E.N.E. There is also a later series of undulations whose axes are nearly E. and W. It is at the intersection of these two sets of anticlinals that the lodes outcrop. They have, therefore, a roughly elliptical form (Fig. 2) in some cases, as at Goldenville, the length of this ellipsis being little more than twice its width, while in others, as at Harrigan and Ecum Secum, the length may be seven or eight miles, while the width is less than two. There is generally more than one lode in a bed of slate. The richer lodes do not average more than

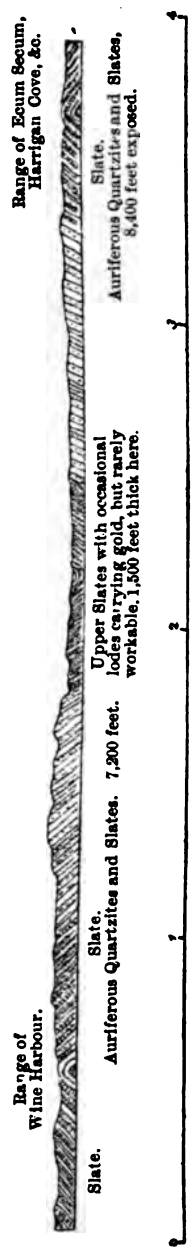


FIG. 1.—SECTION ACROSS CAMBRIAN ROCKS OF NOVA SCOTIA.

eighteen inches thick, but vary greatly in width. The poorer ones have been found up to seventy feet wide. The accompanying slates and cracks in the quartzites often hold gold, which appears to have been introduced with stringers of quartz from the lode. The slate between two lodes not far apart is

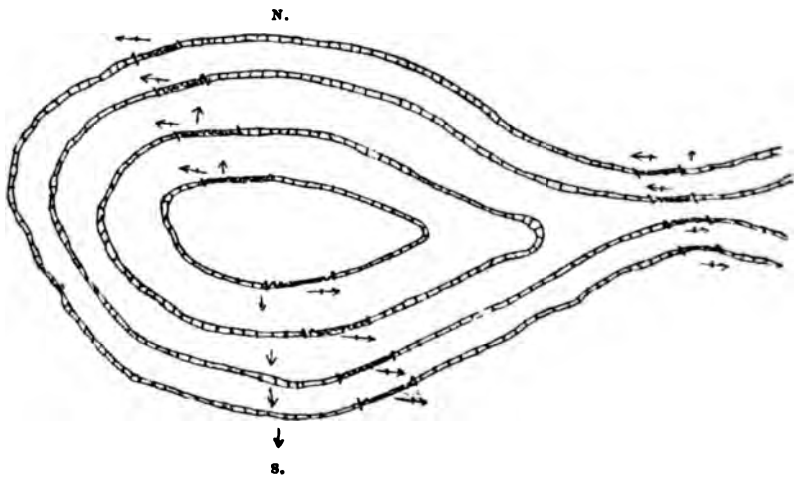


FIG. 2.—PLAN OF OUTCROPS OF FOUR LODES, SHOWING OUTCROPS OF PAY-STREAKS AND ELLIPTICAL FORM.

⟶ Dip of lode. +⟶ Dip of pay-streak.

generally worth crushing. It is generally considered that a "rolling" lode (Fig. 3), a lode, that is, varying much in width,

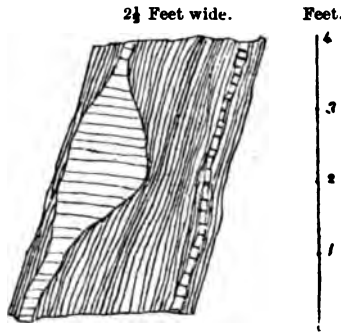


FIG. 3.—A ROLLING LODE.

is the richest, holding gold in great quantities in the swells or rolls. Thus at Uniacke 13 tons from a roll gave 234 ounces;

at Montague 80 tons gave 500 ounces, and 15 tons, 146 ounces; and at Waverley 5 tons, 90 ounces.

A great deal of the gold occurs in visible grains and nuggets, but some of the richest lodes appear to show it very rarely. Mispickel is the commonest associated mineral, but iron-pyrites, zinc-blende, galena, and copper-pyrites also occur. Tin has also been found in auriferous alluvium, but it may not have come from the auriferous lodes. Galena in small quantities in a lode is considered a sure sign of gold.

Very few fossils have been found in these beds, and they are badly preserved. Professor Selwyn found some similar to those from Sweden named *Eophyton*, but Professor Dawson considers they are more likely to be trails of aquatic animals.* Professor Hind found others which Billings referred to *Eospongia*, and casts of *Orthis*. It may be well to quote Dawson's description of the former as seen near Waverley Mine. "Occurring on the weathered surface of the rock, they consist of little oval depressions surrounded by raised ridges, from which radiate a number of raised lines, sometimes bifurcating These lines appear to represent radiating plates or lamellæ rather than rods. They are of various sizes, from one inch to seven inches in diameter, only the larger ones having the rays well developed. They present no structure or evidence of organic matter except that the centre has a brownish colour as if from the oxidation of iron, and that in some specimens differently preserved from others the rays also show a rusty colour. The most natural interpretation of this would seem to be that they consist of a central axis or cavity surrounded by vertical radiating plates sometimes splitting into two towards the circumference. The central axis seems to be the original structure to which the radiating plates were afterwards added. Some specimens seem to indicate that the larger ones were ultimately broken down into irregular groups of plates and separate plates. The material would seem to have been organic and probably very perishable. They have no structures warranting their reference to *Eospongia*, although they might well be compared with the object from the Eophyton Sandstone of Sweden, described by Linnarson under the name

* The presence of organic structure or matter and the organic origin of *Eophyton* or any similar "fucoids" are alike more than doubtful. (*Vide* 'Proc. Geol. Assoc.,' vol. x, p. 468.)—Ed.

Astylospongia radiata. To me they appear to be fucoids with radiating fronds, allied in form to *Phytopsis* from the Bird's-eye Limestone or *Scolithus* from the Eophyton Sandstone." The only other fossils known are specimens resembling the worm tribes, known as *Scolithus*.

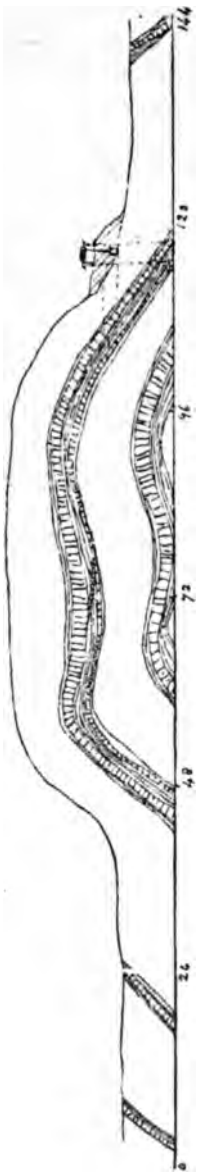


FIG. 4.—ECUM SECUM ANTICLINAL.
Slate.
Lode.

There is a remarkable scarcity of calcareous rocks and minerals. Calcite sometimes occurs in the lodes, but appears as a rule to be of later date. It may be presumed that the lodes were formed during the folding of the strata between which they lie. The fissures which were formed between the sandstones and shales, now respectively quartzites and slates, by their yielding unequally to the pressure, were filled with deposits of silica, which was probably in great part dissolved out of the quartzites by superheated waters, and metallic sulphides with gold brought by the same agency from below. The pressure would be a source of great heat. In the process of folding the greater part of the slate adhered to the lower bed of quartzite. The principal lodes, therefore, occur on the hanging wall. There is very commonly a synclinal fold on the crown of the anticlinal (Fig. 4). In some mines where the lodes are not considered worth working in depth these synclinals have provided *bonanzas*. It appears that at Cochran's Hill granite veins cut the quartzites and slates and are themselves cut by the lodes, showing that the lodes are of later date than the granite, which is supposed to be of Devonian age. Lodes often occur which have quartzites on both sides,

having been deposited between two beds of that rock. They are usually narrow and very regular, and are considered to be generally richer than the other lodes. The richer lodes contain large quantities of mispickel, galena, and sometimes specular iron. Occasionally, however, very rich lodes carry gold in nuggets, and have few minerals. It is probable that the deposition continued for a very long period, and was intermittent. On the renewal of the pressure and consequent reopening of fissures the quartz already deposited, having had time to consolidate, drew away with it some of the adjoining slate, thus making a new opening, in which the future deposits were made. It is found that a lode will in this manner divide, and the two divisions run within a few inches or less than an inch of one another for some distance, and then join again.

A curious effect of the lateral pressure was seen at some places, as at Waverley and Oldham, on the crown of the anticlinal, which has been termed barrel quartz (Fig. 5). The lode

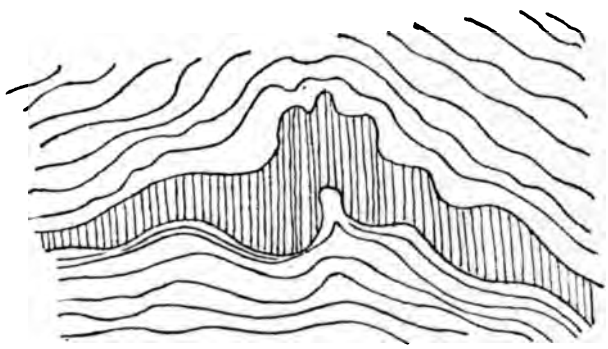


FIG. 5.—BARREL QUARTZ, WAVERLEY. (After DAWSON).

resembled a series of columns placed side by side, and "proves conclusively that the quartz veins are contemporaneous with the folding of the rock, since they have perfectly followed its folds without fracture" (Dawson). Occasionally cross lodes have been found worth working. One occurs at Brookfield, and has been worked for four years. It seems to have held out in depth, as this mine produced 492 ounces from 512 tons in four months of 1889. There is also a lode of the same kind at Millipsigate which has been said to show gold over a length of

two miles. One at Caribon gave 20 ounces, value £78, to the ton.

Gold occurs not only in the quartz but also on the edge of the lode, and sometimes in the slates themselves, where there appear to have been cracks. Stringers of quartz carrying gold sometimes ramify into the quartzite walls. It appears to be deposited in paystreaks, which are sometimes lenticular and die out before reaching the surface. These have been mined on to a depth of 400 and 600 feet vertically in certain cases, when the fact of their passing into adjoining property has caused the works to cease. The Wellington lode at Sherbrooke was worked to a depth of 1,000 feet along the dip of this paystreak, when the difficulty of working without sinking a new shaft stopped it. The miners have a theory that there can be only one paystreak on a lode, and that it ought to die out at 200 feet. The theory has, however, no foundation in fact, for two paystreaks have often been found on the same lode. Dr. Gilpin, Inspector of Mines, who has written a standard work on the Nova Scotia gold mines, says:—"The miner, finding himself confronted by barren quartz, becomes discouraged and abandons his work, when prospecting tunnels would probably have disclosed another paystreak at no great distance." Dr. Sterry Hunt says:—"To abandon a working on account of the momentary impoverishment of a lode, as has too often been done in Nova Scotia, is most unwise. I am of opinion that an unnecessary discouragement has had as much to do with the failure of gold-mining enterprise in Nova Scotia as the want of scientific knowledge and the neglect of proper preparations, and that many of those mines now abandoned as unprofitable will again be taken up with advantage." His words have come true.

The paystreaks dip west on a north dipping and east on a south dipping lode, so that if they lay flat and unbroken these paystreaks would be continuous. There appears to be a streak of galena overlying the auriferous shoot, and underlying it, while copper appears above the galena. This does not always hold good, but is a fairly safe indication of the position of the gold. No search is made for alluvial gold, as it is generally believed that it was all washed into the Atlantic. The present Inspector of Mines says:—"I think the whole secret of the

matter lies in the fact that it has never been sought for with that degree of enterprise, intelligence, and perseverance which the investigation demands. Tangier, Oldham, Renfrew, Waverley, and Sherbrooke present all the conditions for alluvial diggings." At Gaye River a conglomerate of Carboniferous age has been found to contain gold at the base. It was formed of the *débris* of Cambrian rocks which underlie it and have been seen to carry gold. Gold is also known to exist in the boulder-clay, but is difficult to wash, and at the Ovens at Lunenburg is accumulating now on the beach in the hollows of the shingle. We have therefore alluvia of four different periods. It is found in almost every stream in Northern Cape Breton. The yield of gold from Nova Scotia has only amounted to 456,000 ounces, valued at £180,000, from 611,000 tons, besides what has been carried away without record, a small quantity when it is considered how long the mines have been working and the advantages of the country. Only a very small area has yet been prospected, the swamps, forests, and lakes (one-third of the country is water) being great obstacles to prospecting without capital. Few scientific men have turned their energies to working the mines, although Professors Dawson, Silliman, Hind, and How, and Drs. Gilpin and Sterry Hunt have made most valuable reports on the scientific aspect of the question. There is a strong objection in many quarters to any geologist claiming to know anything about mining.

Within the last year or two, more scientific men have turned their attention to Nova Scotian gold mines, and a considerable amount of American capital has been introduced. Capital judiciously expended in better machinery, improved methods of mining and prospecting, and the introduction of more scientific treatment of the ore, should reap a rich harvest. With the mixture of science and practice there is little doubt that better days will dawn for gold-mining in Nova Scotia, and it will be shown that the eminent geologists I have mentioned above were justified in their opinions as to the great capabilities of the Nova Scotian auriferous lodes.

It is curious to note that although no gold was found in Nova Scotia till 1859, its supposed existence there was one of

the principal reasons why France made such endeavours to retain her hold of the country. The reason for the belief was not exactly a scientific one. Native copper exists in the trap rocks of the Bay of Fundy shore, and Lescharbot, writing in 1609, says of it:—"Many goldsmiths who have seen it in France do say that under the copper mine there might be a gold mine, which is probable." They named a bay there the Baie des Mines on account of the supposed mineral wealth there. It is now the Basin of Minas.

The Pebbly and Sandy Beds overlying the Woolwich and Reading Series on and near the Addington Hills, Surrey.

By H. M. Klaassen, F.G.S.

(*Read 6th June*, 1890.)

Early in the spring of the present year (1890) the upper part of the village of Shirley was connected with the main drainage of Croydon and excavations for a sewer were made in a nearly direct line from the Windmill in Shirley road, past the Sandrock Hotel, to 250 feet beyond the Infant School, near the top of the Addington Hills. These excavations have a special interest. They give a continuous section from the Blackheath to the underlying beds and throw some light upon the long-disputed question as to what formation the pebbly and sandy beds, which overlie the Woolwich and Reading series, belong to. Some geologists have classed them with the Oldhaven, others have grouped them with the Woolwich and Reading beds. For years a controversy upon this question has been carried on by Messrs. J. Starkie Gardner, G. F. Harris, Professor Prestwich, and W. Whitaker. The arguments for and against the different views are summarized in Whitaker's 'Geology of London,' Vol. i, pp. 90-102 (1889).

The section, 1,636 feet long, begins on the Addington Hills at a height of 418 feet above Ordnance Datum and ends in Shirley Road, Croydon, at 320 feet.

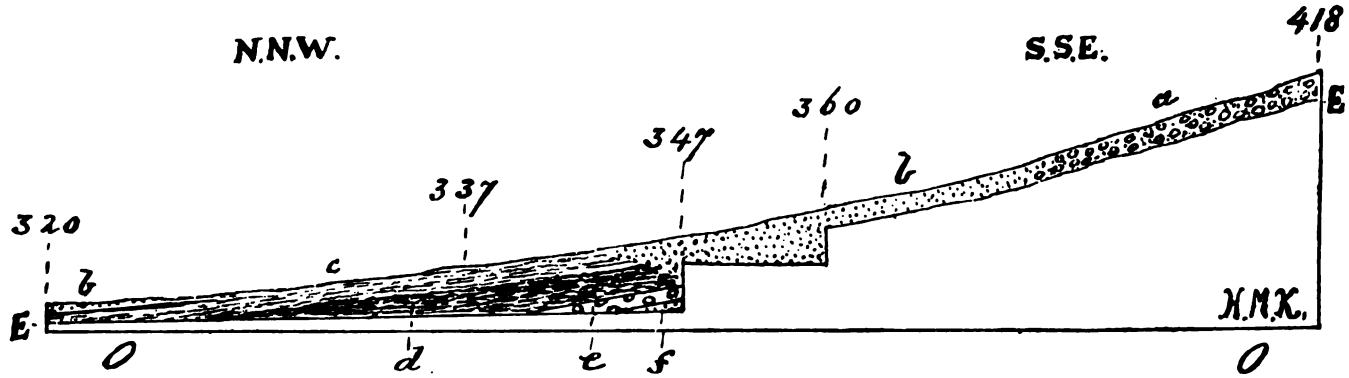


FIG. 1.—SECTION FROM THE ADDINGTON HILLS TO THE WINDMILL, SHIRLEY ROAD, CROYDON.

SCALE: { Horizontal 240 feet = 1 inch.
{ Vertical 80 feet = 1 inch.

a Pebbles in sand.
b Yellow and grey sand.
c Blue clay: Woolwich beds.
d Mottled clay: Reading beds.
e Pebble-rock with mottled clay and green sand.
f Bottom-bed of Woolwich and Reading series.

The figures represent heights in feet at the spots marked.

E. Bottom of excavation.

O. 310 feet above Ordnance Datum.

The excavations show :

	Ft.	In.
On Addington Hills, 418 feet above O.D.,		
Flint-pebbles in light-coloured sand ...	12	0
At the Sandrock Hotel, 360 feet above O.D.,		
Dark brown sand	1	6
Yellow sand, and grey sand with impure pipe-clay	17	6
At the Drinking Fountain, 347 feet above O.D.,		
Flint-pebbles	0	6
Yellow sand	0	9
Grey sand with impure pipe-clay ...	9	0
Mottled clay : Reading bed	12	0
Pebble-rock with mottled clay and green sand	4	0
Green sand : Woolwich and Reading bottom-bed	3	0
At 337 feet above O.D.,		
Woolwich blue and black clay	11	0
Reading mottled clay	9	0
Near the Windmill, Shirley Road, 320 feet above O.D.,		
Pebbles, yellow and grey sand	6	0
Woolwich blue clay	2	0

The sewer excavations afforded little scope for detailed examination, but near the line of excavations there are pits at different levels, where the pebbly and sandy beds can be conveniently examined. The highest bed of the Addington Hills is the Blackheath pebble-bed, consisting of small and large flint-pebbles in a fine sandy base ; the sand is incoherent and without fossils, its colour reddish-yellow, and in long exposed sections yellowish-grey. The exact thickness of the bed could not be ascertained ; in our section it begins at 380 feet above O.D. and is continuous to 481 feet, the highest point of the hill, where bleached pebbles lie exposed on the surface. A trial boring in this pebble-bed was made in 1886 for the Croydon water reservoir, at 472 feet above O.D., but discontinued after it had been ascertained that, at any rate, 50 feet of pebbles were present. Dr. G. J. Hinde, F.G.S., has taken great interest in these excavations and has kindly sent the following abstract from his notes :—

"In 1887 an extensive excavation for a new reservoir was made on the summit of the Addington Hills, entirely in the pebble-beds of the Blackheath or Oldhaven series, which, at this place, crop out at the surface. The beds exposed consisted almost entirely of the usual smooth, dark pebbles of flint, with a slight admixture of fine yellowish or reddish-yellow sand. The materials were generally loose and unconsolidated, though occasionally lumps were formed, where slight cementation had taken place. The sand was not in layers by itself, but irregularly distributed between the pebbles. The face of the section showed at intervals peculiar horizontal or curved lines, where the sand had apparently been removed, and in some places there were dark layers stained by wad.

"The sand, examined under the microscope, consists of very irregularly-shaped grains, mostly sub-angular; in some instances the angles sharp, in others blunted; rounded grains being very rare. The grains are from ·11 to ·37 mm. across. The large majority are of quartz, but many are of flint, and these have the form of thin chips, with sharp edges.

"The pebbles range from approximate spheroids to compressed ellipsoids in form, and in size from half-an-inch to eight inches (12 mm.—20 cm.) across; the great majority are, however, about an inch (25 mm.) in diameter, uniformly smooth and rounded, and their surfaces are covered with a network of microscopic shallow cracks. As a rule they have a shining, dark appearance, but long surface exposure bleaches them to grey. Many of them are in process of decay, when they become of an opaque, porcelain white and their surfaces are soft and powdery. The larger flint-pebbles are usually flattened or cake-shaped; they readily break under the hammer, even when no signs of decay are apparent. Many of them can be seen to be crowded with Foraminifera and sponge-spicules, and these bodies are much more abundant and more distinctly shown in these flint-pebbles than in any fresh flints from the Chalk of the neighbourhood.

"I did not see a single example of a flint retaining its original, sub-angular form, nor any specimen of chert or ragstone derived from the Lower Greensand, and the only exception to the prevalent flint-pebbles which came under my notice were some cake-shaped pebbles of a light-grey quartzite, in form and smoothness of surface very much like the flints, from which, indeed, they could

hardly be distinguished until they were broken. These quartzites are very hard and fine-grained. They appear to be rare. The largest I found was about four-and-a-half inches across by two inches in thickness (110 by 45 mm.). Judging from the character of the rock, they may have been derived from Palæozoic strata, and it is not easy to account for their presence in these Tertiary pebble-beds, associated as they are with Chalk-flint pebbles exclusively. I am not aware that similar pebbles have been previously recorded in the Blackheath or Oldhaven series, but Professor Prestwich has lately stated that large pebbles of white or light-coloured quartzite, now present in the beds of Westleton shingle, may have been derived indirectly from the shingle-beds of the Woolwich and Reading series, where he has occasionally found them, or they may have come from the quartzites of the Palæozoic rocks of the Ardennes ('Quart. Journ. Geol. Soc.,' Vol. xlvi, 1890, p. 146).

"I did not find any shells or other fossils in the beds."

The beds below the one just described are exposed in a large pit in Sandpit Road, near the Sandrock Hotel, where the material has been worked away backwards as far as the Archbishop's park, leaving an almost vertical section of the Oldhaven beds, 31 feet deep. When its weathered face is removed we find the top 10 feet to consist of small and large flint-pebbles in a light-coloured sandy base, interspersed with layers of yellow and grey sand, having non-continuous partings of impure pipe-clay. Current-bedding is distinctly visible. This is followed by 21 feet of grey sand (Oldhaven), with few pebbles, thin layers of impure pipe-clay and yellow loam. From the floor of the pit down to the Reading mottled clay there is a bed of 10 feet of grey, brown and silver sand, with thick layers of impure pipe-clay, but without pebbles. The silver sand is dug for sale. Fossils are not found in the vertical section, nor in the excavation below the floor; a cannon-ball, circumference about $1\frac{1}{2}$ foot, recently dug up at 6 feet below the present surface of the pit, may have an antiquarian value.

My best thanks are due to Mr. Albert Tarn, B.Sc., F.C.S., for the following analysis of the impure pipe-clay :—

"Dried at 100°-105°, about 80 per cent., insoluble in acid, consists of free silica and silicate of alumina. The loss on ignition, due to organic matter and combined moisture, is 3·55 per cent.

COMPLETE ANALYSIS.

Silica	77·86
Alumina	12·67
Ferrous Oxide	2·25
Lime	1·09
Magnesia	·90
Potash	1·40
	96·17
Loss on ignition	3·55
	99·72 "

VERTICAL SECTION OF THE ADDINGTON HILLS.

		Thickness. Feet.
Blackheath beds.	Small and large flint-pebbles in a reddish-yellow sandy base, ranging from 481 feet above O.D. to 380 feet ...	?
	Small and large flint-pebbles in a light-coloured sandy base, with layers of yellow and grey sand and slight partings of impure pipe-clay. Current-bedding	10
Oldhaven beds.	Grey sand, with few pebbles, thin layers of impure pipe-clay and of yellow loam	21
	Grey, brown, and silver sand, with thick layers of pipe-clay, without pebbles	10

The Oldhaven beds rest partly upon Reading, partly upon Woolwich clay.

With regard to the pebbly and sandy beds which overlie the Woolwich and Reading series near the Addington Hills, it will be convenient first to speak about the bed of grey sand with impure pipe-clay (K in Fig. 2) in the Woodside and South Croydon Railway, about the classification of which geologists are divided in opinion. "The sand is incoherent, has slight partings of impure pipe-clay, pellets of clay, some brown clayey layers containing carbonaceous fragments; its bedding is irregular, and the partings of clay, as in fresh-water deposits, are not continuous."* The sand rests upon the white shell-bed, the highest member of the Woolwich and Reading series, and is essentially the same as the grey sand with impure pipe-clay in the Sandpit Road at the Addington Hills. The shell-bed in the Woodside and South

* 'Proc. Geol. Assoc.,' Vol. viii, No. 4, p. 245 (1883).

Croydon Railway also gives evidence that the overlying grey sand is Oldhaven, as flint-pebbles are embedded in its surface.

Near the Addington Hills we have a fossiliferous pebble-bed: a conglomerate of flint-pebbles, sand, blue clay, angular pieces of shells and carbonaceous fragments, cemented together by a calcareous medium. This is overlaid by pebbles in brown sand, occasionally compact, containing whole shells, some with rounded edges, numerous angular pieces of shells and slabs of calcareous sandstones. About similar beds Professor Prestwich remarks: "The difficulty is, whether we are to consider any of the peculiar fossiliferous, sandy, or conglomerate beds of Woolwich, Bromley, or adjacent districts as a fuller development of the basement stratum of the London clay, or whether they all belong to a distinct and underlying series. I am inclined, on structural evidence, to the latter opinion; nevertheless, on palæontological grounds it might be presumed that a passage here exists between the two series. We, however, yet feel the want of a few good sections to settle clearly this point."*

The position of the fossiliferous pebble-bed near the Addington Hills is shown at *i* in the following Section. It lies in the hollow of the eroded Woolwich clay, and is overlaid by the Oldhaven grey sand with impure pipe-clay.

The whole shells, those with rounded edges, the numerous angular pieces of shells, the flint-pebbles with oyster-shells attached which this bed contains, show that the Blackheath pebbles drifted gradually into their present position. A sudden coming-in of the pebbly mass would have ground the shells to powder. The descent of the pebbles upon the Woolwich beds broke up the greater portion of the shell-bed, the highest member of the Woolwich series, leaving only a length of 160 feet at *h* in Fig. 2. Its fossils—*Cyrena*, *Melanopsis*, *Melania* and *Ostrea*—are found in the pebble-bed. After the destruction of the shell-bed, the currents that deposited the pebbles eroded the soft Woolwich clay, containing *Cerithium*, *Cyrena*, *Hydrobia*, *Melanopsis*, *Melania*, *Neritina*, *Nucula*, *Ostrea*, *Paludina*, *Planorbis*, *Pectunculus*, *Unio* and lignite, and these fossils also are present in the pebble-bed. Professor Prestwich places *Coryphodon Croydonensis* and *Gastornis* in this bed,† but they really belong to the Wool-

* 'Quart. Journ. Geol. Soc.,' Vol. vi, p. 262.

† 'Geology: Chemical, physical, and stratigraphical' (1888), Vol. ii, p. 346.

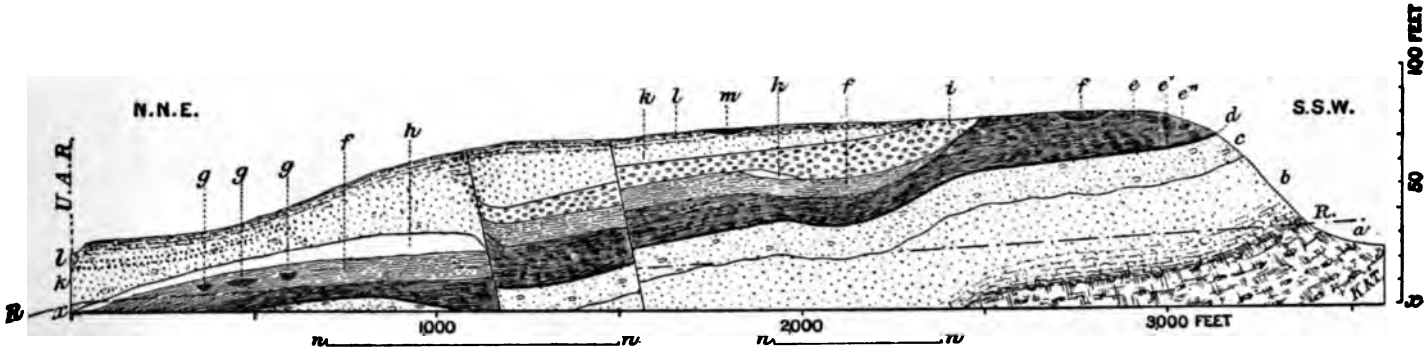


FIG. 2.—PARK HILL SECTION ON THE WOODSIDE AND SOUTH CROYDON RAILWAY.

SCALE: { Horizontal 528 feet = 1 inch. Vertical 80 feet = 1 inch.

200 feet above sea-level.
Chalk.
Thanet beds.
Woolwich and Reading Bottom-bed.
Lavender-coloured sandy Pebble-bed.

e Mottled clay (fluviatile).
e' e'' Pockets.
f Blue clay (estuarine).
g Lignite beds.
h Shell-bed.

i Fossiliferous Pebble-bed.
k Grey sand with impure pipe-clay.
l Brown and grey laminated clayey sand.]
m Drift.
n n Tunnels.

R. Railway Level. *U.A.R.* Upper Addiscombe Road.

wich beds, and were found by me in the soft clay in the north cutting of the railway.

The material of the sandy, fossiliferous and conglomerate pebble-bed belongs for the most part to the Oldhaven beds, composed of sand and pebbles. The Woolwich beds contributed the shells and clay and cemented the pebbles and sand into a massive bed, a fossiliferous puddingstone.

The particulars of a sewer excavation in Oaks Road, at the foot of Addington Hill, may also be worth recording. The Oldhaven beds there rest upon the Reading mottled clay.

Oaks Road, at the junction with Shirley Road:—

		Feet.
Blackheath pebbles, yellow sand, and grey sand with impure pipe-clay		10
Reading mottled clay		12
Pebble-rock with mottled clay and green sand ...		4
Green sand: Woolwich and Reading Bottom-bed...		3

Oaks Road, at the first manhole:—

Blackheath pebbles in sandy base		1
Reading mottled clay		2
Pebble-rock with mottled clay and green sand ...		1
Green sand	Woolwich and	3
Brownish-green sand	Reading	6
Grey sand	Bottom-bed ...	2

I am indebted to Mr. Thos. Walker, Engineer to the Borough of Croydon, for kindly providing me with the levels for my Section.

Notes on Some Pleistocene Sections in and near London.

By W. J. Lewis Abbott, F.G.S.

(*Read March 7th*, 1890).

*Section A.— Whitefriars.**—The chief interest in this section is that it connects the historic and the prehistoric.

The section is a somewhat generalized one from man-holes† and other excavations in the neighbourhood of Whitefriars and represents a line drawn from Fleet Street, through Salisbury Square, to the Embankment. You will all have observed that on looking down on the south side of Fleet Street and the Strand the streets dip towards the Embankment. This hill roughly represents an old bank, cut through the Palæolithic gravels (*a*) by the river at a later period, somewhat modified by made ground (*e*), which in Fleet Street is sometimes only four feet thick, whilst over the lower



Fig. 1.—Generalized Section in Whitefriars, Fleet Street to the Embankment.

part it often attains a thickness of 10 feet to 15 feet. At a few feet from its top in Fleet Street there is a well-marked Palæolithic floor in these gravels. Near the crest of the hill in Salisbury Square, at 14 feet 6 inches from the surface, just on the top of the blue London Clay, at ×, a very large jaw of *Rhinoceros antiquitatus* was found, and from the same horizon, within a radius of a mile or so, I have obtained most of the larger Pleistocene mammalia.

On the flanks of the old gravel bank there comes a dirty sandy

* *Vide supra*, p. 342.—Ed.

† It is impossible to obtain correct measurements in cases like this, without being on the spot all the time, so one has to take the measurements and details as given by the workmen.

gravel of the later river series (*b*), probably of the Bronze Age, as I was informed by the workmen that articles of bronze were found at the bottom of the next bed above it. It is very remarkable how this post-palæolithic series varies from peat and dirty carbonaceous sandy clays to bright, sharp, clean, highly-coloured sands and gravels, sometimes extending a great way under the river, and sometimes only with difficulty separated from the underlying Drift. This is shown by numerous sections made by the late Metropolitan Board of Works, by railway companies, and for wharves, etc., and eastward where the area has been sinking, the beds are now many feet below the level at which they were deposited, and probably contain the last relics of our extinct mammalia together with implements that bridge over the by-some-supposed gap between the two Stone ages.

Upon this gravel rests a layer of peat (*c*),* which attains a maximum of 3 feet, from which it thins out towards the Thames, very much discolouring the beds both above and below it. I have recognized willow, beech, and oak in it, and no doubt a botanist would greatly swell the number of plants. When we first meet with it, it is about 6 feet above Ordnance Datum. I saw it for two-thirds of the way down the streets between Tudor Street and the Embankment in over a dozen places, but beyond these the twelve or fourteen feet man-holes did not reach it. I was informed by the foreman of the works that it had been reached at greater depths near the Embankment. I think it most probable that it reaches the old foreshore under the Embankment at about Ordnance Datum. He also informed me that the London Clay was reached at twenty-five feet, near the Embankment. If so, there is one of those rises and falls that one meets with in the London Clay along the river-edge.† In it I found bones of goose, *Bos*, and sheep, and the skull and antlers of a stag, together with numerous other bones. In one place there was a quantity of oyster shells, and mussel shells in another.

This peat is followed by a somewhat dirty gravelly sand (*d*), six or eight feet thick, containing *Sphærium rivicola* Leach; *Pisidium amnicum* Müll.; *P. fontinale* Drap.; *P. pusillum* Gmel.; *Cyclas* sp.; *Unio tumidus* Retz.; *Neritina fluviatilis* Linn.; *Paludina vivipara* Linn.; *Bythinia tentaculata* Linn.; *Valvata piscinalis* Müll.;

* In some places the peat rests immediately on London Clay.

† Compare the series of sections given in 'Mem Geol. Surv. Geology of London,' Vol. ii, p. 252.

Planorbis corneus Linn.; *P. albus* Müll.; *P. marginatus* Drap.; *Limnæa peregra* Müll., and a fish-bone. There was a good deal of wood, of willow, oak, pine, alder, sedges, etc., and stones of wild plum, wild cherry, and a grape,—the latter, no doubt, introduced by the Romans,—Roman pottery, chiefly Samian ware, and Roman coins of the first century, A.D. Upon the heap thrown up was a shell of *Dreissensia polymorpha* Pall, in the same state of preservation as the other shells. If this lived here, we shall have to modify our idea of the date of its introduction into Britain.

This sand is covered by made ground (*e*) without the interposition of any fire-layer.

East and west extension.—These fossiliferous sands do not cross the Valley of the Fleet; or if they did, they have been removed. Sections lately made in Water Lane and at Apothecaries' Hall show that the London Clay rose very high and very quickly here, forming an almost vertical cliff. In the cross section just mentioned the London Clay was 28 feet below O.D., and at Water Lane, only 300 yards east of it, it is 20 feet above O.D, and is not covered by gravel (as shown in Survey Map), but by made ground. There have been a number of sections made lately which also show slight differences—a circumstance that must necessarily follow from the unavoidable conditions under which any survey is made, whence the necessity of recording local sections as they are laid bare. I have noticed several times in the Valley of the Fleet, sections of small gravel-depositing streams tributary to it, some historic, others prehistoric; but perhaps these might have been known, but considered too small and insignificant to map. At the south-west corner of Hosier Lane, Smithfield, a section showed made ground 4 feet, resting on a fire-layer which at the south side rested on light brown London Clay (changing as sharp as a line to dark green glauconiferous sandy clay at another four feet or so), while at its north side there was a section of half a river-channel of gravel, from which Mr. Greenhill has since informed me he obtained some extra fine implements. A little higher up the valley, at the corner of Clerkenwell Road, I saw on a London Clay island bank three septaria that had been subjected to fire, with over a peck of burnt carbonaceous matter surrounding them. From here I also obtained an implement, with what appears to be traces of adhesive material on it.* Another cutting in St. Andrew's Street

* Gough's 'British Topography,' Vol. i, p. 719 (ed. 1780), speaking of

showed a section of a stream, probably the Old Bourne,* that gave its name to Holborn. Westward, however, these later river-beds are extended, as shown by sections in Arundel Street, Surrey Street, etc.

At the bottom of Salisbury Street, Strand, 80 yards from the Embankment, below the made ground, there was four to five feet of the sand, thinning out to nothing on the north, containing bones of a brown colour, and about 18 feet of old gravel, down to the London Clay, which was 28 feet deep.

Mr. B. B. Woodward has published a section of "the Opera House," showing the peat at 10 feet, and 15 feet of very interesting sand under it, containing bones of *Bos primigenius* and stag.

Section B.— West Thurrock.†—This section takes us to the classic neighbourhood of Grays, about which so much has been written from Professor Morris downwards. No account, however, has, I think, been published of any section so far west as this, which is four miles west of Grays, the nearest (from which, however, it differs sufficiently to be worth noting) being to the east of that place.‡ Indeed, so much do these sections differ in detail that, although so close together, they often cannot be easily correlated, owing to the different conditions under which they were deposited and to the fact that beds upon the same horizon often represent different phases in the history of the river, older beds being cut into by newer ones. Hence the necessity of detailed individual accounts.

We have first the most northern limit of the river at this spot, at which time it flowed against the Chalk escarpment (*a*), which was probably considerably over 50 feet high and very vertical. The lower bed (*b*), near the shore, is a sandy gravel. The pebbles in it are rather small on the whole, more being below three-quarters

John Conyers, "apothecary, one of the first collectors of antiquities, especially those relating to London, when the city was rebuilding," says, "He inspected most of the gravel-pits near town for different sorts and shapes of stones. In one near the sign of Sir John Oldcastle, about 1680, he discovered the skeleton of an elephant, which he supposed had lain there only since the time of the Romans, who in the reign of Claudius, fought the Britons near this place, according to Selden's notes on the Polyolbion. In the same pit he found the head of a British spear of flint, afterwards in the hands of Dr. Charlett, and engraved in Bagford's letter." The "Sir John Oldcastle" was in Cold Bath Fields, Clerkenwell.—ED.

* More probably the "Hole-bourne," or brook in the hollow. See 'The Holebourne,' by J. G. Waller, 'Trans. London and Middlesex Archæol. Soc.,' Vol. v.—ED.

† *Vide* p. 365 *supra*.—ED.

‡ "Geol. Lond.," Vol. i, p. 418.

of an inch in diameter than above. They are chiefly flint, well rounded for the most part, and probably derived, as was the greater part of the bed, from much older beds; but there is a very large proportion of saccharoid quartz, various coloured quartzites and

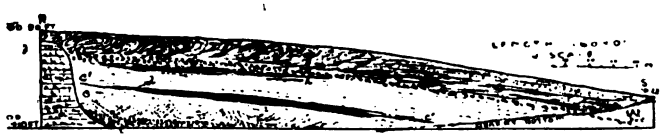


FIG. 2.—SECTION AT WEST THURROCK, ESSEX.

jaspers, lydian-stones, chert, and, here and there, though very rarely, a pebble of volcanic and metamorphic rock. The accompanying sand is a very light grey, almost white, and is usually very free, although occasionally panned by iron or manganese. Near the base of the cliff there is a layer of large angular flints, which appear to thin out streamwards, where the gravel becomes much coarser and much more obliquely bedded. It passes under the marshes, where it is sometimes worked, and where I have found rolled bones in it, and also flakes, of the human origin of which I have not the slightest doubt, but no trace of mollusca.

This gravel is followed by a light brownish grey sand (*c*), which attains a thickness of upwards of 30 feet, extremely cross-bedded at its lower parts, indicating strong current action. This action seems to have died out as we go up the bed, until, by the time we get two-thirds up, it was no longer able, we find, to transport even sand, but only mud, especially near the shore, or at a little distance from it. Here the clay (*d*) thickens out to three feet, and gradually thins out streamwards for over 600 yards. Another impetus succeeded, and once more it brought down fine sand, depositing it horizontally (*c*) without any signs of cross or current-bedding. This sand, however, became more marly as the current lost its strength, and once more a marly clayey bed was deposited (*e*), which reaches a maximum of five feet, and continued streamward we cannot say how far, for in the next stratum we have evidence of something very violent compared with what had ever been known on these shores. A layer of heavy, large, subangular gravel (*f*), in a light sandy matrix, reaching a maximum of 18 inches, now appears

ploughing up some of the last-named clay, and at 80 yards from the cliff it entirely cuts it away, mixing confusedly with it. Whatever may have been the original conditions under which this was deposited, it is absolutely certain that it, and also the superincumbent beds, have been subjected to great pressure, and that the gravel carried along with it a great deal of either calcareous material, which has since been carried away in suspension, or, what is far more probable, and to my mind certain, ice, which has since left the interspaces comparatively hollow, whilst above and below the flints are crushed and crumpled, and the sands and clays tightly bound. This gravel is followed by about 10 feet of mixed stony clay and loam (*g*), the whole of which has been greatly disturbed and turned over and crushed by the latest fit of glaciation. Over the top of the Chalk, and down its then existing cliff, the contortions are charming, one on reaching the cliff bent upon itself in a graceful fold of a 12-feet sweep, exhibiting in one section all the phenomena of underplight, trail, and warp. That denudation of the Chalk here was very great, is certain from the large masses of flint, sometimes six or eight feet thick, all pitched with their axis at right angles to the resistance and along the curves of the underplight.

Fossils of the Sands.—Not the least interesting point about this section is the fine series of mammalian remains that have been here preserved in the sand by the overlying impervious clay bands. Usually in sands and gravels the percolation of water goes on so freely as to allow of the removal of all calcic material; but in this instance the bones have been singularly preserved. Here perhaps I might be allowed to say a word or two on the preservation of bones in river drifts and other deposits. The Chief Clerk at Brompton Cemetery, which is in gravel, told me that they dug the ground over again every seven years without finding a trace of former interments. I have noticed in all sands and gravels that, unless they are specially protected, bones soon disappear, but in proportion to accompanying calcic material, or admixture of marl, they are preserved. Usually, if the bones go into the deposit fresh, there is formed round them a mechanico-chemical compound, sometimes two or three inches thick, which is much stronger than the bone itself; and, in proportion to the clay, or perhaps some other material, present, the bone ultimately assumes an amorphous condition, approximating in appearance to the substance we know as "race." It has, indeed, struck

me that this might be the origin of race, seeing that one always finds it in, or derived from, clay. I, therefore, kept looking for a confirmation of this idea, which, I think, I have laid on the table to-night in the form of a large dorsal spine, one end of which was deposited in somewhat clayey sand, and the other in dense blue clay. As it lay in the beds one could see that it originally was one bone. Now I am sure that, whilst sufficient of original structure is left in the end buried in the sand for identification, no one would hesitate to pronounce the other crumbly end to be race, although the whole thing represents every intervening state. I intend to have this quantitatively and qualitatively analyzed at various positions. The results no doubt will prove interesting, and show the animal origin of this compound, thus accounting for our often finding race in clays when we expect to find bones.

There was one most interesting stratum here, several yards long and eight inches to ten inches thick (*h*), which, when exposed in section, looked altogether too large to be of organic origin, but upon driving my hammer into it I found it to be crushed ivory! How such a mass as this, some of the blocks three or four inches square, and one or two inches thick, could have got together, is a mystery. The nearest thing I ever saw to it was a picture lately sent home by Stanley, where the ivory had been collected and stored on the low shore of a river, and I must say that I could not help my mind immediately picturing the man of this period storing up the trophies of the mighty tuskers, leaving them for a while, and, on coming back, being unable to find them from their having been covered with a flood-loam as one there saw it.

Although the bones occur scattered through this longer bed, they were always far more plentiful just under the clays. In one place, I really believe, from the great depression in the underlying marl, that an elephant must have pitched over the cliff, and, from the large number of his bones that were untombed, I got nearly twenty of his vertebræ, which were inclined over on to each other, most of his ribs, including the characteristic first one, four teeth, his longer limbs, his toes, and also his huge pelvis.

I have had a monopoly of this section for eight years, during which time only a few hundred yards have been removed. The following is a list of the species in the order of the abundance of the bones:—*Elephas primigenius* Blum., teeth and every description of bone; *Rhinoceros leptorhinus* Owen, jaws, upper and lower, uncut,

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milk and permanent teeth, and nearly every bone; *Bos taurus* v. *primigenius* Boj., vertebræ, horns, teeth, and many other bones; *Cervus elaphus* Linn., horns, leg-bones, &c.; *Equus caballus* Linn., teeth, leg, toe, and other bones; *Cervus giganteus* Blum., pieces of horns, leg and other bones; *Hippopotamus amphibius* Linn., vertebræ, one tooth, &c.; whilst honours are about equally divided between the following (many of the bones of which cannot be specifically determined satisfactorily): *Elephas antiquus* Falc.; *Rhinoceros megarhinus* Christ.; *R. antiquitatus* Blum. Bison (?). Many of these are of exceptionally large size.

It will thus be noticed that in this section we have probably 11 out of the 15 Pleistocene Ungulata.

Fossils of the Upper Beds.—I should have been disposed to have made these upper beds much younger than the lower ones, from the unconformity that exists at the flint bed, but a diligent search has produced bones, usually in a very bad state of preservation, of *Elephas*, *Bos*, horse, and *Cervus* (probably *giganteus*), which practically are the same as those below. They also contain a molluscan fauna, generally much crushed, but occasionally very perfect, consisting entirely of univalves, so far as my discoveries are concerned. These include *Bythinia tentaculata* Linn.; *Valvata piscinalis* Müll.; *Planorbis corneus* Linn.; *P. albus* Müll.; *P. marginatus* Drap.; *Limnæa truncatula* Müll.; *L. peregra* Müll.; *L. sp. ?*, *Pupa muscorum*, and the aberrant variety of *Helix ericetorum* just described by Mr. Woodward (p. 365 *supra*).

Brief Notes on the Geology of the Mendip Hills,

With reference to the Long Excursion, August 4th to 9th, 1890.

By Horace B. Woodward, F.G.S., of the Geological Survey of England and Wales.

The Mendip Hills may be described as for the most part a table-land that stretches from Frome in a north-westerly direction to the Bristol Channel, a distance of about 30 miles. As we proceed towards the coast the ground becomes more diversified, and the hills more and more detached. The elevation varies from about 450 to 1,060 feet, and the breadth of the tract is from three to five miles. Nevertheless, old writers, who united more poetry than we do to their descriptions, speak of these hills as a "chain of mountainous land," or as the "Alps of Somersetshire;" while Crook Peak, near Axbridge, which rises to a height of 640 feet, and is certainly the most prominent of the hills, is spoken of as "a prodigious eminence."

The hills are said to owe their name to their mineral wealth, they were called the "Myne Deeps" (written "Munedappe" in old records), and have yielded up their lead-ore to the ancient Briton and the Roman. In later times both galena and calamine were worked with considerable energy, but seldom to a depth of more than 30 fathoms. Little has been done of late years, except to work-up the refuse left by the old lead-miners, but this material is found to yield on an average about 12½ per cent. of metal.

The Mendips owe part of their charm to the fine views they afford. To the north lies the vale of Wrington, with Dundry Hill and the Cotteswolds beyond. To the south extends the plain of Sedgemoor, with distant views of the Wiltshire Downs on the south-east, and of the Quantocks on the south-west.

To the traveller in search of the picturesque, the combes and cliffs are the most attractive features in the district. The Cheddar Pass exhibits the grandest inland cliffs we have in this country,

while the Ebbor Rocks, Burrington Combe, Vallis, and other ravines afford much beautiful rocky scenery.

To the geologist, of course, the charms of scenery are enhanced by her or his ability to decipher some of the records of the rocks; and these old rocks, extending it may be said from the Old Red Sandstone to the Forest Marble, are freely exposed to view, without those adjuncts of boulder clay, which in the midland, eastern, and northern counties leave so much for the scientific use of the imagination. But if we miss these relics of the "Great Ice Age," it must be remembered that changes went on despite the absence of the deposits, whether of this or earlier ages, and the missing chapters mean denudation in one form or another.

Yet another source of interest to geologists is the association of the district with the "hammerers" of old days. The results of their labours invest the rocks with a spell they would not otherwise possess; and although papers written fifty and more years ago are sometimes regarded as "ancient history," they are as a rule far more readable than the majority of those produced nowadays, and they are for the most part quite as instructive.

Somersetshire has had a considerable share in the development of geological knowledge. The relations of its Coal-measures to the overlying "Red earth" and "Lyas" were shown as early as 1719 by John Strachey, while towards the close of the same century, William Smith was actively engaged in setting out and superintending the works on the Somersetshire Coal-Canal, thereby gaining much of that knowledge which has formed the chief foundation of our science. Smith, however, did not enter much into the geology of the Mendip Hills. The main features in the structure of this range were made out by William Buckland and W. D. Conybeare, whose 'Observations on the South-western Coal District of England' were communicated to the Geological Society in 1822. Three years previously, however, an excellent account of the western portion of the range had been furnished by Thomas Weaver, an old pupil of Werner's at Freiberg, and a man who did much careful geological work. Both these papers were published in 1824.*

Conybeare at this time held a lectureship in the church at Brislington, near Bristol, and was thus intimately associated with the district, and the full account of its geology (accompanied by a

* 'Trans. Geol. Soc.,' Ser. 2, Vol. i, pp. 210 and 317.

map) which he published in conjunction with Buckland, has been the basis of all subsequent work on the Mendips and adjoining areas. On this ground Sedgwick learned some of his earlier geological lessons in 1819, and again in 1820, when he first made acquaintance with Conybeare, whom he came to regard as his master in the subject. Together they examined the country near Bristol and the Mendips, where Sedgwick recognized the same limestone he knew so well about Sedbergh. The two geologists parted on the top of the Mendips in 1820, and Sedgwick then proceeded to Wells.*

Later on we had the Geological Survey Maps, of which the Mendip area was chiefly done by De la Beche, aided by W. T. Aveline. The former added largely to our knowledge of the physical history of the area in his famous essay 'On the formation of the rocks of South Wales and South-western England,' while the denudation of the country was enlarged upon by [Sir] A. C. Ramsay.† De la Beche, indeed, had previously examined much of the ground (as mentioned in the work by Buckland and Conybeare), and he always showed much interest in its geology.

Subsequently William Sanders, of Bristol, personally surveyed the entire area of the Mendip Hills and Bristol Coal-fields on the scale of four inches to one mile, publishing his map in 1862.

While these geologists had interpreted the general structure and physical history of the Mendip Hills, the subject had been by no means exhausted. More detailed observations carried on during a number of years by Charles Moore, of Bath, enriched our knowledge very largely. He discovered a very important exposure of eruptive rocks that had hitherto eluded the notice of previous geologists, and he made many remarkable discoveries of fossil remains in the fissures that traverse the Carboniferous Limestone near Frome. Born on the Lias of Ilminster, he made that formation, together with the Rhætic Beds, the subjects of special study; and it may be said of the Rhætic Beds that they owe their recognition as independent in this country to his enthusiastic researches.‡

* 'Life and Letters of Sedgwick,' by J. W. Clark and T. McK. Hughes, Vol. i, 1890, pp. 217, 218.

† 'Mem. Geol. Surv.,' Vol. i, pp. 1 and 297. The second edition of the Geol. Surv. Map of the district was prepared by H. W. Bristow, H. B. Woodward, W. A. E. Ussher, and J. H. Blake (1867-71).

‡ 'Quart. Journ. Geol. Soc.,' Vol. xvii, p. 483; Vol. xxiii, p. 449.

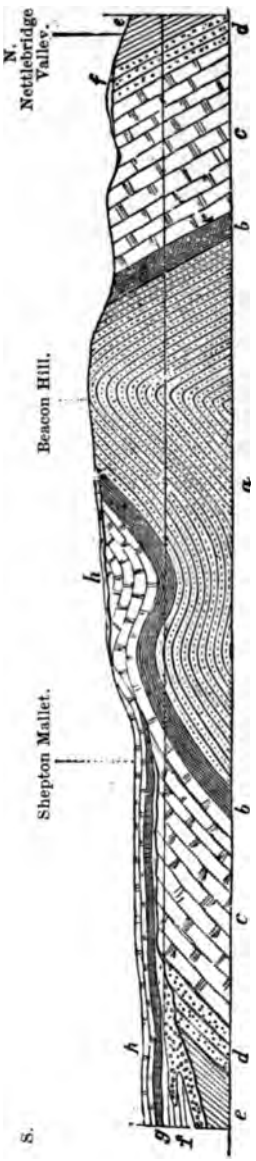


FIG. 1.—SECTION ACROSS THE MENDIP HILLS. Horizontal Scale an inch to one mile.

[H. B. Woodward, 'Geology of England and Wales.' *Edit.* 2.]

A. Lower Lias.
g. Rhætic or Penarth Beds.
f. Red Marl and Dolomitic Conglomerate (Keuper).
e. Coal-measures.
d. Millstone Grit.
c. Upper Limestone Shale and Carboniferous Limestone.
b. Lower Limestone Shale.
a. Upper Old Red Sandstone.

The general structure of the Mendip Hills is usually expressed in the term "Mendip Anticlinal." In reality the table-land is formed of a series of denuded anticlines, which trend in an easterly and westerly direction, and thus do not coincide with the north-westerly and south-easterly direction of the range (Fig. 1).

There is evidence of at least five folds—the summits of which in four instances have been laid bare sufficiently to expose the Old Red Sandstone. As in the case of some of the remarkable folds in the Secondary rocks of the south and south-east of England, the strata on the northern sides of these anticlines usually plunge downwards much more steeply than on the southern side; and there are vertical strata and symptoms of slight overfolding at one or two points on the northern side of the Mendip Hills (at Churchill Batch and near East End, Leigh-upon-Mendip), as well as in the Steep Holmes, an islet in the Bristol Channel.

Connected with the disturbances that produced these anticlines, are the disturbed Coal-measures, on the southern side of the Somersetshire Coal-field, and the small masses of Carboniferous Limestone that appear amidst them, and apparently over them. In one instance, at least, near Upper Vobster, as pointed out by Mr. G. C. Greenwell in 1861,* coal has been worked beneath the older Limestone; and the general evidence is in favour of these isolated masses of Carboniferous Limestone having been brought abruptly over and against the newer Coal-measures. Various theories have been propounded to account for the abnormal positions of these rocks.

Mr. J. McMurtrie has argued that the Limestones were folded over from the Mendip range on the south;† while I have endeavoured to account for their position by a faulted and inverted anticline, which I should connect with that of Pen Hill on the west, rather than with that of Downhead on the south.‡ The Rev. H. H. Winwood has published some most important facts which have come to light at Upper Vobster since these explanations were attempted. They introduce to our notice on the south side a small tract of Carboniferous Limestone, dipping northward and overlaid by Upper Limestone Shales and Millstone Grit. This mass is

* 'Trans. N. Inst. Mining Eng.,' Vol. x, pp. 110, 115, and 'Trans. Manchester Geol. Soc.,' Vol. v, 1864-65.

† 'Proc. Bath. Nat. Hist. Club,' Vol. iii, p. 287 (and other papers).

‡ 'Geol. Mag.,' 1871, p. 153; 1876, p. 455; and 'Geol. East Somerset,' etc., p. 194.

faulted on the north against an inverted mass of the same series of strata, including also Coal-measures. Still further north the Coal-measures are brought abruptly against another mass of Carboniferous Limestone, "so much disturbed that the dip is difficult to make out," but particular portions dip N., S., N.W., and E. Mr. Winwood has most carefully recorded the facts, but considerately leaves the explanation for others. I saw portions of the section in 1885, but not the inverted strata, which were proved in a tunnel. The facts confirm in a general way that part of my original section of 1871 which represented the Carboniferous Limestone and Millstone Grit to be inverted on the north; but we still have to account for the presence of non-inverted Limestone on the south, and the tumbled and faulted Limestone on the north. So far as I can judge, the minor disturbances attending a great faulted and inverted anticline might account for the phenomena.*

Since "thrust-planes" have come into prominent notice Mr. W. A. E. Ussher has suggested that one of these more or less horizontal displacements affected the Downhead anticline, carrying forward a portion of the saddle of Carboniferous Limestone, etc., over the Coal-measures on the north. In this way, with the help of minor faults and denudation, he would account for the isolated masses of Carboniferous Limestone.† He has, however, not gone so far as to publish any section.

It should be borne in mind that Somersetshire for the past 25 years has been known to possess a "thrust-plane," familiar as the Radstock "slide-fault," or "overlap-fault." By this disturbance, particulars of which have been made known by Mr. McMurtrie, portions of the Coal-measures have been forced over other portions of the same beds from south to north, to a distance of from 120 to 330 yards.‡

Subsequently other striking instances of reversed faulting were discovered nearer Bristol, as pointed out by Handel Cossham; it is, however, to Mr. McMurtrie that we are most largely indebted for our knowledge of the faults and disturbances in the Somersetshire Coal-field. I have been unable to accept his "overthrow theory" to account for the position of the Vobster Limestone, because I could draw no diagram that would explain the facts by an overfold

* 'Proc. Bath Nat. Hist. Club,' Vol. v, p. 24; and part for 1890.
† 'Rep. Brit. Assoc.' for 1888, p. 659.
‡ 'Proc. Bath. Nat. Hist. Club,' Vol. i, p. 127.

from the Mendips near Downhead; and he himself has not ventured to give an explanatory section, contenting himself with the cautious statement that the beds "must in some way have been folded over from that range, although we may not be able to realize how all this has been brought about."*

The disturbed state of the Coal-measures on the south side of the Coal-basin has been mentioned; there the beds are so broken and contorted that it is said the same coal-seam has been thrice penetrated in one shaft. The general structure of this portion of the Coal-field has been justly compared with that of the Belgian Coal-fields, where similar violent disturbances are met with, and where the qualities of the coals are said to be similar. But it should be borne in mind that while Coal-measures have now been met with at Dover, we have no grounds for assuming that the possible underground tracts of Coal-measures between that locality and the Somersetshire Coal-field, occupy any more regular positions among the folded Palæozoic rocks than do the known Coal-basins in the western and midland areas.

With regard to Prof. Rücker's observations on the particular magnetic attractions met with along certain lines of country,† it may be said that at present they need not seriously disturb our notions on the possibility of underground areas of Coal-measures, even within a short distance of such places as Reading, where the compass-needle was more powerfully affected than in some other tracts. For along the Mendip Hills, in the Old Red Sandstone, near Downhead, there is the dyke discovered by Mr. Moore, an eruptive rock that contains much magnetite;‡ and yet within two miles productive Coal-measures are worked.

The country to the south of the Mendip Hills, and more especially perhaps that near Evercreech and Glastonbury, offers a favourable tract for speculative boring, for at present no one has ventured deep enough on this side of Mendip to prove the nature of the Palæozoic floor. There are, I believe, traces of Millstone Grit at one point, south of Dinder, and again to the west of the Ebbor Rocks; both localities being on the southern side of the range. (See Fig. 7, p. cxciii, *supra*).

* *Ibid.*, Vol. iii, p. 299.

† A. W. Rücker, "On Underground Mountains," 'Good Words,' Jan. to Mar., 1890. See also paper by W. Whitaker, and discussion, 'Journ. Soc. Arts,' Vol. xxxviii, April, 1890, pp. 543, etc.

‡ See F. Rutley, in 'Geology of East Somerset,' etc., by H. B. W., p. 208.

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The oldest rocks of Mendip, the Old Red Sandstone, consist for the most part of red and brown micaceous sandstone, with quartzose conglomerate; the latter disintegrated in places into a kind of gravel. No fossils, beyond obscure plant-like markings, have been recorded from the Old Red Sandstone of Mendip, but some fish-remains have been found at Portishead, near Bristol. There is a gradual passage upwards from these rocks into the Lower Limestone Shales—well shown north of Black Down, in a gully that leads towards Burrington Combe, and here the passage-beds yield Trilobites, of the genus *Phillipsia*. These beds comprise alternations of sandstone and shale, merging upwards into the main mass of shales, and these, higher up, contain bands of limestone, and pass thus gradually into the Carboniferous Limestone. Both Lower Limestone Shales and Carboniferous Limestone yield many fossils, but at present the beds on Mendip have not been very carefully searched. Thin Upper Limestone Shales occur above, and these are succeeded conformably by Millstone Grit and Coal-measures. The disturbances that produced the Mendip folds took place in the interval between the period of the Coal-measures and that of the Trias. The eruptive rock of Downhead may then have been intruded. Sir A. C. Ramsay, who drew sections to show the amount of material removed from the hills, calculated the loss as amounting in places to 6,000 feet. Be this as it may, the entire tract bears evidence of great denudation, and in many cases we have actual evidence of very even plains or terraces of denudation. This is conspicuous in the vales near Frome, and may be observed near Wells.

Of succeeding strata, the oldest comprise the beds of Dolomitic Conglomerate, that were marginal accumulations of the Keuper Marls. These beds consist of breccia and conglomerate formed mainly of angular and rounded fragments of Carboniferous Limestone, cemented sometimes by a dolomitic matrix, but often by ferruginous matter and carbonate of lime. Much of the material is evidently due to sub-aerial waste of the land, being the angular detritus cemented at or near the spots where it accumulated; other portions have been more or less rolled.* Remnants of this Dolomitic Conglomerate occur along the higher grounds of Mendip, as well as along the borders of the range.

* De la Beche, 'Mem. Geol. Surv.,' Vol. i, pp. 243, etc.; and C. Lloyd Morgan, 'The Mendips: A Geological Reverie,' p. 19.

Of the succeeding Rhætic Beds we have had good exposures along the Great Western Railway west of Shepton Mallet, described by Charles Moore; at Milton Lane, near Wells, described by the Rev. P. B. Brodie; and along the Great Western Railway at Uphill, described by Sanders, Bristow, Etheridge, and others. Where we find these beds on the Keuper Marls, we have a gradual passage upwards of Grey Marls, Black Shales (with *Avicula contorta*, etc.), and White Lias. The Lower Lias comes on in entire conformity. Traces of Cotham Marble, which occurs at the base of the White Lias, are to be seen here and there, as at Stone Easton on the north, and East Horrington on the south of the Mendips. Rhætic sandy beds, with *Pullastra arenicola* and *Avicula contorta*, occur on top of the Mendips, at Harptree Hill, while remarkable infillings of Rhætic material have been found in the fissures of the Carboniferous Limestone by Moore. Attention will be called to some of these fissures near Frome, where there have been obtained, teeth of the Mammal, *Microlestes Moorei*, and of the Fishes *Acrodus minimus*, *Gyrolepis Alberti*, *Hybodus reticulatus*, *Saurichthys acuminatus*, etc.

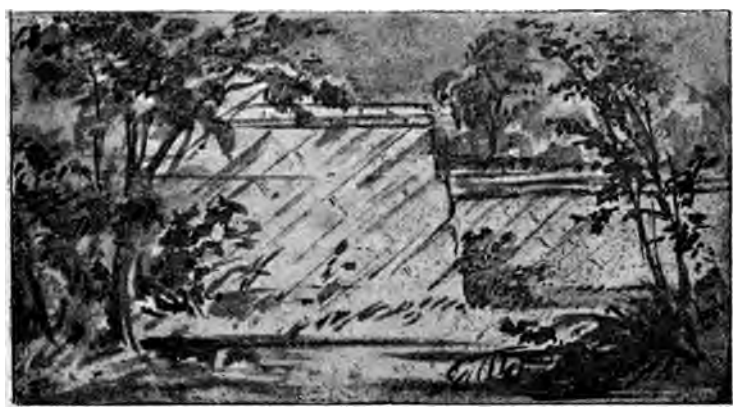


Fig. 2.—Section in Vallis—Showing Inferior Oolite resting on Carboniferous Limestone.

(After De la Beche.)

It is noticeable that where the Triassic and Lower Jurassic Beds abut against the Mendips, we find evidences not only of conglomeratic conditions, but of attenuation and overlap, so that some-

times Dolomitic Conglomerate, sometimes Rhætic Beds, Lower or Middle Lias, or Inferior Oolite will be found directly on the older rocks. The plain or terrace of denudation on which, in some cases, the strata rest, may have been formed at an earlier stage than that of the particular deposit now resting on it, previous accumulations having been swept away (Fig. 2).

The varying positions occupied by these Secondary strata on the flanks and higher grounds of the Mendips are likewise in part due to marginal deposits being laid down at different relative levels, and in part to subsequent faulting or irregular elevation.

The Rhætic Beds, Lower Lias, and Inferior Oolite exhibit conglomerate conditions, and the Lower Lias also exhibits considerable modifications, as will be seen at Shepton Mallet. There we have a rock like the Sutton Stone of Glamorganshire, a pale and more or less granular and tufaceous kind of limestone, containing occasional fragments of chert derived from the Carboniferous Limestone. The proximity of the Lias to this Limestone appears to have had something to do with the lithological characters of the rock. We find very similar beds of Lias on Broadfield Down, north of the Mendips.

On Harptree Hill we find a very distinct and still more remarkable form of Lower Lias. There it appears in layers of a hard pale-buff cherty rock. Fortunately these beds have yielded fossils such as *Ammonites planorbis* and *Ostrea liassica* that prove their age. How the rock came to present these characters may still be considered a puzzle. It is true that I offered an explanation in the days of my youth.* I compared this cherty Lias with that at Portrush in the N.E. of Ireland, where the beds have been metamorphosed into a dark cherty rock by contact with eruptive rock. On the Mendips we have no evidence of eruptive rocks nearer than Downhead. It is, however, possible there may have been some intrusive rock which did not find its way to the surface, but made its influence felt by the agency of heated water. This, in short, is the hypothesis I ventured to advocate; and the fact that the Triassic Beds in the neighbourhood are also of a peculiar cherty nature lent some support to the notion. I may add that near Frome the Inferior Oolite, in places, exhibits a very cherty character. Mr. McMurtrie has called attention to this.

The Members will have the opportunity of seeing the ordinary

* 'Geol. Mag.,' 1871, p. 400.

beds of the Lower Lias at Street, near Glastonbury, and also at Shepton Mallet, while the Middle and Upper Lias are to be seen at Glastonbury Tor. This remarkable conical hill, a monument, as it were, of the denudation of surrounding areas, is capped by the Midford Sands. These beds form a passage between the Upper Lias clays and the Inferior Oolite. No fossils have been obtained in them at Glastonbury, but one species of Ammonite, to which the name *Grammoceras fallaciosum* has been affixed, has been obtained by Mr. Hudleston from these beds near Cranmore.* The Sands do not, as a rule, occur near the Mendip Hills, being overlapped by the higher beds of the Inferior Oolite (Fig. 3).

The Inferior Oolite will be seen at Doulting, but the quarries do not offer many temptations to the collector. The beds belong to the zone of *Ammonites parkinsoni*, that species being obtained by Moore, and Mr. John Phillis, of Shepton Mallet, has lately discovered *Terebratula morieri*, a species hitherto only found in this country at Bradford Abbas.† Passing upwards in the geological scale, something may be seen of the Fuller's Earth near Frome. As a rule it is very fossiliferous, especially when we get an exposure of the Fuller's Earth Rock. No traces of the Bradford Clay have been exposed, though it should be present at the base of the Forest Marble. The shelly and oolitic limestones of this group have been quarried in many places near Frome, and indeed the rock is locally known as "Frome stone."

These and other Jurassic rocks must at one time have buried up the Mendip Hills, and, after a certain amount of uptilting, they all suffered considerable denudation during the great Cretaceous overstep. Both Upper Greensand and Chalk must have spread over the Mendip Hills and far away. Their present outcrops are within easy reach of Frome, the neighbourhood of Warminster being one of the most famous localities for Upper Greensand fossils.

Thus the Mendip area has seen great changes since its old rocks were plicated. It has suffered denudation again and again, and when laid bare in Post-Cretaceous times it has been more or less continuously weather-beaten.

Many of the fissures and fractures are of old date, containing

* S. S. Buckman, "Inferior Oolite Ammonites," 'Pal. Soc.,' p. 168.

† The specimen was presented to the Museum at Jermyn Street by Mr. S. G. Perceval.

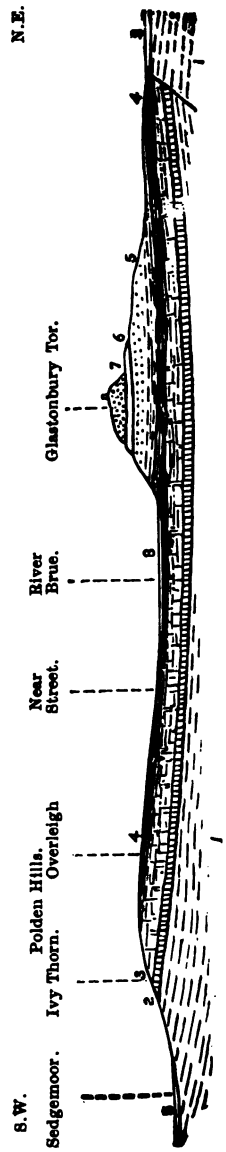


FIG. 3.—SECTION THROUGH GLASTONBURY TOR.

[H. B. Woodward, 'Geology of England and Wales.' *Edit.* 2.]

4. Clays
3. Limestones } Lower Lias.
2. Rhætic Beds.
1. Keuper Marls.

F. Fault.
8. Alluvium.
7. Midford Sands.
6. Upper Lias.
5. Middle Lias.

metalliferous deposits, of which detrital portions have been found in the Secondary strata. Infillings of Rhætic and Liassic material doubtless took place at different periods, and a commingling of material is seen in some cases to have resulted. It may be, as Moore suggested, that certain open fissures received material during Rhætic and Liassic times, for along modern cliffs of Carboniferous Limestone, as in Glamorganshire, great chinks occur here and there into which the breakers cast much detrital material.

Many of the great fissures on Mendip, originating along joint-planes or lines of fracture, have been so enlarged as to form caverns and ravines; the latter in some cases (as suggested by John Phillips) having resulted from the former. The solvent action of carbonated water, aided by frost and streams, mainly contributed to the result. In the case of Cheddar it will be seen that the dip of the strata has exercised much influence on the shape of the cliffs—what may be called the conservative side standing up boldly and precipitously and exhibiting but little change in the course of years—while the other side, the dip-slope, may be said to be exceedingly liberal. It affords abundant evidence of the disintegration of the land, sending showers of detritus now and again on to the roadway beneath. To such radical changes we owe nearly all that is beautiful in our scenery. The base of the Cheddar Pass is now a well-paved road; hence the stream, which lies buried underground, can exert no influence on the fallen blocks, and it is needful for man to remove the spoils of denudation (Fig. 4).

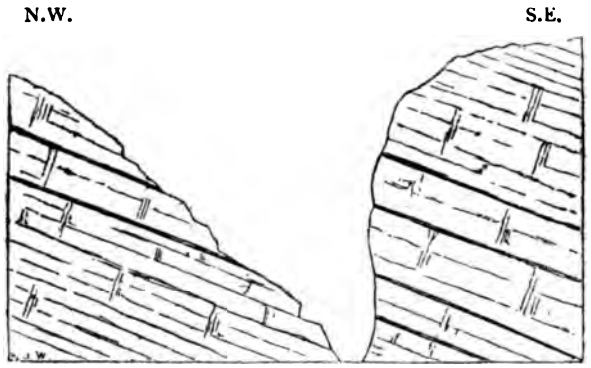


FIG. 4.—DIAGRAM SECTION OF THE CHEDDAR CLIFFS. H. B. Woodward. *(Reduced from Geological Survey Memoir.)*

To reply to the query, when were the Cheddar Cliffs and other ravines formed? it may be answered that all are, to some extent, in

process of formation. The underground streams still carry away much carbonate of lime in solution, and they must abrade the fragments that strew their courses. Thus the *débris* that annually falls, sinks down (where it can) to be in turn acted upon. It is difficult to form any notion about the period when these chasms may have been commenced. Joints, no doubt, originated from the original consolidation of the strata. Fractures attended their earliest upheaval and folding. Rains, perhaps, beat down on portions of the elevated ridges in Triassic times and widened the cracks; but in course of time they were, in a measure, sealed up by Jurassic and Cretaceous sediments, and we know that materials of Jurassic age filled some of the old fissures. No doubt the main features, as we now see them, were marked out long after this great covering was removed, and from the later Tertiary period to the present day would give ample time for the work. It must be remembered too that the drainage-areas would have been vastly different before the vales on either side of the Mendip were excavated; and for long periods subterranean waters may have exerted their solvent powers.

Excepting the fissures containing Jurassic material, we have no evidence of caverns or crevices with fossil remains of earlier date than the later part of the Pleistocene period, and there is reason to believe that all the main features we see had then been outlined by rain, rivers, and estuarine action, agents which may have exerted a more potent influence during some of the vicissitudes of Glacial times.

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